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WITH

THE APPLICATION OF GEOMETRY TO ROOF TILING,
REMARKS ON THE DIFFERENT KINDS OF POINTING,
A DESCRIPTION OF THE MATERIALS USED BY THE BRICKLAYER

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PRACTICAL, PLANE AND SOLID GEOMETRY, ETC.

ILLUSTRATED WITH NINETY-ONE WOODCUTS

Third Edition



LONDON

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A. I. L.

PREFACE.

THE object of this little work is to give the young artisan a general and practical insight into his trade, and to inspire him with a wish to become a useful and successful workman; which means that he must work with his head as well as with his hands. The greater portion of the matter contained herein is such as to be indispensable to the proficient workman. Though the work does not profess to be in any way an exhaustive treatise on a trade so varied as that of the brick-layer, yet the writer hopes that it may be a help to those who, through the division of labour or otherwise, have had their practice confined to one branch only of their trade; and that it may not be considered altogether unworthy the notice of professional men, being to some extent the outcome of twenty-two years of practical experience in building operations. It is, however, intended

chiefly for that large majority of young men who enter the trade of the bricklayer (and all other trades in house-building) without any previous training or instruction to fit them for the calling, depending entirely upon the manipulative skill they may or may *not* acquire in the handling of their tools. The book commences with the site of a building, and goes through the successive stages of the bricklayer's trade, including roof tiling; and concludes with a section on Applied Geometry, containing problems that may be useful in every-day practice.

LONDON, *September*, 1884.

NOTE TO THE SECOND EDITION.

THE very rapid and gratifying sale of the first edition, and the favourable manner in which it has been received by the various technical journals, have led the author to make several additions and a few alterations to the work, with a view to increasing its usefulness not only to the operative student, but also to those who may be preparing for the Science Examination in Building Construction.

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BRICKWORK.

SECTION I.

MATERIALS AND GENERAL PRINCIPLES OF CONSTRUCTION.

SITE.

THOUGH the bricklayer is very seldom called upon to choose the site of a proposed building, he should nevertheless make himself acquainted with the essentials of a good foundation, and the characteristics of a bad one, as a subject not altogether foreign to his calling. The workman who rests satisfied with just the manipulative knowledge of his own trade is not likely to realise the value of the word *progress*, and must of necessity be content to remain in the position in which he found himself placed as a workman. Though the bricklayer has no voice in the choice of site, he may, as foreman or clerk of works, have to a great extent the power of minimising the evil effects of a bad one, if he be possessed of the necessary knowledge. For be it remembered that a good foundation is as necessary to the stability of a building, as good flues and drains are to the health and comfort of its occupants. The best sites to build upon are hard gravel, igneous and

metamorphic rocks, limestones, sandstones, and chalk. A clay foundation should be well drained, as clay by its impervious nature retains moisture, and the whole area of the site covered with 6 inches of surface concrete, made up with Portland cement or ground blue lias lime, to keep back ground-damp, which will otherwise be attracted by the warm air within the building. When building on a clay or sand foundation the building should be kept level throughout, as by building up one portion of the building and leaving down another, ugly fractures sometimes occur in the walls, caused by one portion of the work settling at one time, and other portions at another, which greatly mar the appearance of the structure.

ESTABLISHING A LEVEL OR DATUM.

Before excavating trenches to receive concrete for footings, a level, or *datum* as it is technically called, should be established. To do this, drive a large stake well into the ground where it will not be likely to get disturbed, and let the top of it be the ground-floor level, which must be taken off the drawings if not otherwise determined. To avoid the possibility of mistakes, all levels for excavations, concrete, and brickwork should be taken from this only.

SETTING OUT BUILDING.

In setting out a building, one or other of the following methods is generally adopted. Either the extreme side walls are squared from

the line of frontage, which is given, and the positions of the intermediate walls established by parallels; or, two centre lines are drawn at right angles, right through the plan of the building, and the walls set out at parallel distances from them; taking all measurements from the centre lines. The positions of walls should not be laid down by measuring the distance of one wall from another in succession; for if an error be made in the setting out of the first wall, it will, in this way, be perpetuated from one wall to another throughout the building. But by measuring from the centre line, an error would be confined to that particular wall in connection with which it was made, and would be readily discovered when checking the distances between the respective walls. In both methods we have assumed the building to be square. If the setting out is to be

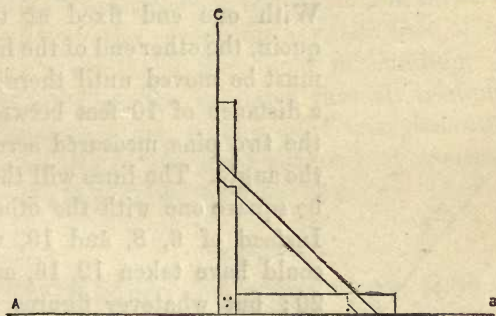


Fig. 1.

done by means of a large square, which is generally the case, it should be tested or proved before use.

To do this, draw a line *a b* along a straight

edge (Fig. 1), not less than twice the length of the base of the square. Adjust the base of the square along this line from *b*, and draw a line *c* along the perpendicular blade until it meets the base line *a b*; now reverse the square along the base line from *a*, and if the square be true its perpendicular will coincide with the perpendicular line *c*. Another way of setting out the side walls from a given line of frontage is by means of a 10-feet rod. Having drawn a line tightly to represent the front of the building, along this line measure 6 feet from the quoin (French *coin*, a corner), and push through the line at the 6-feet point an ordinary brass pin. Draw another line in the same way as the first, approximately at right angles to it, and from the quoin again measure off 8 feet along *this* line, fixing another pin as before at the 8-feet point.

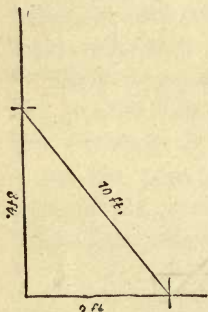


Fig. 2.

With one end fixed at the quoin, the other end of the line must be moved until there be a distance of 10 feet between the two pins measured across the angle. The lines will then be square one with the other. Instead of 6, 8, and 10, we could have taken 12, 16, and 20; but whatever figures be used must stand in the same ratio or proportion to each other as the above, and shown in Fig. 2.

Another Method.—From point B (Fig. 3), with

steel measuring tape set off 30 feet, or more or less as convenient, at an approximate angle of 45 degrees with the given line A B. From D mea-

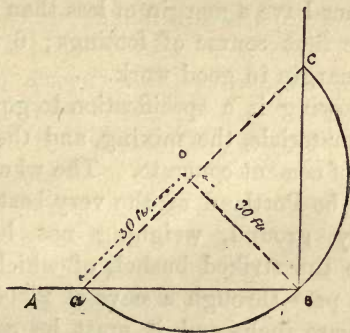


Fig. 3.

sure off the same distance to *a*; from *a* draw a line through *d*, measuring from *d* to *c* 30 feet. A line drawn from *B* through *c* will be at right angles to the given line A B, the line of frontage; *B* would be the quoin of building. This depends upon the principle that all triangles in a semicircle are right-angled triangles, and all the angles in the same segment of a circle are equal (*Euclid*, bk. iii. prob. 21).

CONCRETE.

The thickness for concrete varies from 1 to 3 feet, according to the nature of the subsoil upon which the building will stand; but in some cases it is very much thicker, as in made-up ground, where, to ensure a good foundation, it is necessary

to go down to the London clay, or some other firm substratum, depending upon the nature of the ground. The Metropolitan Building Act requires that the concrete shall not be less than 9 inches in depth, nor have a margin of less than 4 inches outside the first course of footings; 6 inches is the usual margin in good work.

The following is a specification to govern the supply of materials, the mixing, and the putting into place of cement concrete. The whole of the cement to be Portland of the very best quality, very finely ground, weighing not less than 110 lbs. to the striked bushel, of which 90 per cent. must pass through a sieve of 2,500 meshes to the square inch, and it must be capable of maintaining a breaking weight of 350 lbs. per square inch, after being made in a bronze mould immersed in water during an interval of seven days.

The mixing to be carried on upon a clean platform made of 9 inch \times 3 inch deals, bedded solidly on sand, that the cement may not run off through the joints in the process of mixing. The concrete to be composed of four parts of broken bricks, broken porous stone, or Thames ballast; two parts sharp clean sand, free from loam or other impurities; and one of cement of the specified quality. The parts to be measured in a half-yard cubic box (3 feet \times 2 feet \times $2\frac{1}{4}$ feet), and thoroughly mixed together in a dry state. The ballast or broken bricks to be capable of passing through a 2-inch mesh. The dry concrete to be heaped up and

turned over at least twice before wetting. The water to be applied through a rose, not more to be used than is necessary to mix the whole very thoroughly. While the water is being sprinkled on, the mixture should be drawn down by "picks," while two or more other men turn it over, after being so drawn down, to another part of the platform, from which it must be again turned over until the parts are thoroughly incorporated. The concrete to be tipped from a height not exceeding 4 feet, and to be steadily rammed or struck with the back of a shovel until the cement or matrix flushes to the surface. The whole to be left solid and clean.

In the treatment of concrete much depends upon experience and judgment, and it is therefore the more difficult to lay down hard and fast rules to govern the proportion of the ingredients and the mixing of them. The one thing to be aimed at in the apportionment of the ingredients is homogeneity; where this does not exist, strength will be wanting.

As regards "packing," or the practice of placing stones or other suitable material larger than the aggregate, in the mass of the concrete, it is objectionable under certain conditions. In a thoroughly good Portland cement concrete, if properly treated, there will neither be contraction nor expansion to any perceptible degree in the setting; and in such there is no objection to packing, if the stones or other material be uniformly distributed and solidly bedded in

the mass. But in an inferior concrete subject to contraction or expansion, packing is decidedly objectionable, and likely to lead to injurious results; more especially if the packing be not evenly distributed throughout the concrete. This consideration has led engineers and architects to adopt in their specifications the precautionary clause that the aggregate shall be of an uniform size—generally, to pass through a 2-inch or $2\frac{1}{2}$ -inch ring.

The quantity of water to be used depends almost entirely upon the nature of the aggregate; ballast or any siliceous aggregate requiring only enough to thoroughly mix the cement, while that of a porous nature, such as broken bricks, would require more. The proportion of cement must be governed by circumstances, for while the Metropolitan Main Drainage Works adopted one of cement to five and a-half of aggregate, we are informed by Mr. Reid *On Concrete*, that in the sea forts of Copenhagen the concrete was made in the following proportions:—

Portland cement	.	.	.	.	1
Sand	.	.	.	.	4
Fragments of stone	.	.	.	.	16

and the concrete for filling in the terra-cotta at St. Paul's School, Kensington, consisted of one of Portland cement and ten of aggregate.

In Portland cement concrete, "a rotten or friable material is to be avoided, except where unavoidable, and in that case only in combination with a large quantity of cement, so as to neutralise

as far as possible any tendency to weakness. Sand, where a choice exists, should be as rough and coarse as possible, and that made by the various natural or physical influences from sandstone, limestone, or other similar rocky formations, is to be preferred over those from flint or volcanic rocks. The former sands or shingles are more porous than the latter, and consequently better able to absorb the silicates of the cement when being mixed. For this reason it is advisable not to have the sand, gravel, or shingle too fully saturated with water; if this is so, the matrix is unable to imbibe the fluid portion of the mixture, and consequently it is thrown off as waste from the concrete. This observation equally applies to the mischievous practice of over-wetting bricks in building with cement mortar. A dry brick is bad enough, but when saturation is carried to excess equally faulty results ensue. With regard to the acting properties of Portland cement when used with salt sand, or salt water, an experiment proved the use of salt water and salt sand perfectly satisfactory, both with Portland cement and lias lime, but there was no question as to their setting being retarded by their use."—*Brunel*.

When blue lias is used for concrete, the proportion of parts and the mixing is the same as described in cement concrete.

Burnt ballast is frequently used as an aggregate for concrete, but care should be taken that it be thoroughly burnt free from clay. Burnt ballast concrete should be made rather sloppy on ac-

count of its absorbent nature, or it will quickly absorb the moisture from the cement or lime with which it is mixed, to the injury of its setting properties and ultimate strength.

Mixed with one-third of Thames ballast and a fair proportion of lime it will yield a good concrete for footings to walls.

CEMENT.

Adie's No. 1 cement testing machine is very generally used for testing cements, but where one of these is not at hand they may be

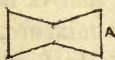


Fig. 4.

roughly tested in the following manner. Having mounted a briquette (Fig. 4), whose sectional area is one square inch, or more as the case may be, after seven days' immersion let it be suspended from one end, and from the other end suspend a cement barrel containing sand, increasing the quantity until the briquette breaks or its power of resistance be overcome. The sand should not be thrown into the barrel, but slid into it by means of an inclined plane, and in small quantities. The weight of the cask with its contents will represent the breaking weight. With Adie's machine the briquette in the making is subjected to a slight pressure, which adds considerably to its tensile strength, so that the resistance to breaking of a briquette made by the machine will be greater than that of a briquette of the same cement made by hand and not subjected to pressure. Another way: bed two bricks together (Fig. 5), and after

a few days' immersion let them be suspended and treated in the same way as the briquette. This plan is suitable for ascertaining the comparative strength of cements, but in so doing the same kind of bricks, sand (if any used), and even water should be used, and the exact proportions maintained in the mixing, or, in other words, the conditions should be exactly the same. Bricks having a smooth impervious bed will be found to have less adhesion than those of a hard but comparatively porous nature—pressed bricks and hard stocks, for instance.

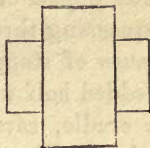


Fig. 5.

The bricklayer should make himself acquainted with the various limes and cements, and the ingredients used in combination with them; also with concrete, as subjects belonging particularly to his trade, and which by reason of his occupation he has a better opportunity of doing than any other class of operatives. In large and important public works these are generally subject to the inspection of a bricklayer.

DRAINS.

The laying of drains, at once the most important and too frequently the most neglected part of a building, should never be intrusted to unskilled workmen. The fall having been determined, which should not be less than one in sixty or one inch in five feet, the flange of each pipe should rest upon a bedded brick, that the joints may be

caulked all round with gaskin or oakum previously to being made up with Portland cement. The object of caulking is to prevent the cement squeezing through into the pipe, a very common cause of stoppage in drains. They can now be bedded half way up in fine concrete, so as to form a cradle, care being taken not to disturb the joints. The inside joint of each length of pipe as it is laid should be stopped with Portland cement, and left solid and clean, free from anything approaching to burrs. The drains should be laid down air and water-tight, free from "dips," with no right-angled junctions nor sharp bends, and kept, if at all possible, outside the building, with inspection holes large enough for a man to work forcing-rods in case of a stoppage. A length of pipe in the man-hole should have a movable top. This kind of pipe is called an *operculum* or "channel" pipe. In many instances only the invert half of the pipe is used in that portion of the drain passing through the man-hole, which is ventilated by a current of fresh air entering the man-hole, passing through the entire length of the drains, and finding an outlet through the open soil-pipe above the roof. In such an arrangement a trap should intervene between the sewer and the man-hole, to prevent the possibility of sewer gas escaping through the fresh air inlet. But where fresh air is not introduced, the trap may be dispensed with, the soil-pipe serving as a ventilator both for the sewer and the drains.

Six-inch pipes will be found large enough for most buildings. As the subject of trapping, disconnecting, and ventilating drains belongs to sanitary science, it cannot be further noticed here beyond giving a plan and section of a dip-trap (Figs. 6 and 7) which the bricklayer is sometimes

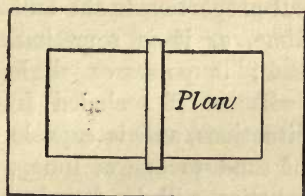


Fig. 6.

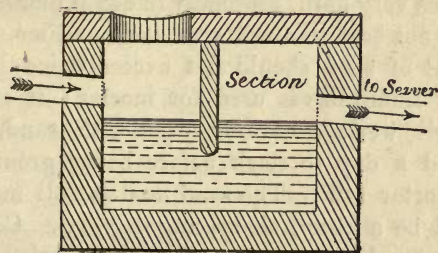


Fig. 7.

called upon to build. This trap should be used only where there is a copious and frequent supply of water (but not in connection with soil), as by its size and construction a greater quantity of water is required to trap it than the earthenware traps now more generally and preferably used.

MORTAR.

Mortar used by the bricklayer is made either from stone lime, lias, or Portland cement, mixed with a proper proportion of sand. Chalk lime should not be used, as the only setting that takes place in it is the formation of a surface crust, bearing a small proportion to the bulk. Stone, or gray chalk lime, as it is sometimes called, is generally used; it possesses slight hydraulic power, and will set if secluded from the air or in damp situations, and is capable of bearing three parts of sand to one of lime. For damp situations blue lias will be found to make the best lime-mortar. It is eminently hydraulic, and becomes very hard, especially in damp places; but it will not bear so much sand as stone lime. The amount of sand should not exceed twice that of lime. Lump lias is used for mortar; it should be well wetted, covered over with sand, and allowed a day to slack before being ground in the mortar mill. The sand used for all mortars should be a clean, sharp, angular grit. Cement has been already spoken of in connection with concrete, and elsewhere.

RED BRICKWORK.

Owing to the revival of the Queen Anne style of architecture, brickwork now occupies the foremost position in building construction, of which very good samples may be seen at Westwood House, Sydenham; Fitz-John Avenue, Hamp-

stead; the Chelsea Embankment, and many other places in and about London. Our popular architects delight to revel and indulge their fancies in red brickwork, as evidenced in several public buildings of recent erection. The Victorian age, from an architectural point of view, will be conspicuous for its stuccoed buildings and its red brickwork—the former an expressionless imitation, the offspring of the speculator, and the Caliban of architecture. But Truth in architecture, as in all things, *will* assert herself; she breathes into the nostrils of a second Adam, and lo! we have “a thing of beauty.”

We can remember, in our experience, when the life of the bricklayer was often made “bitter with hard bondage in mortar and in brick,” by reason of the reign of stucco; but, thanks to the able advocacy of Mr. Ruskin and the late Mr. E. Street, such rapid strides have been made in brickwork that one is almost surprised to see the amount of art-workmanship wrought in red-brick designs.

These will be found mostly in retired out-of-the-way streets, relieving, both by colour and detail, the dull monotony of the unbroken line of our vista-like old street architecture.

Some years ago the Philological School, St. Marylebone Road, was pointed out as a sample of ornamental brickwork. The ornamental features in this structure are made up of a judicious use and arrangement of polychrome bricks, and stone dressings. The building is, undoubtedly, a good one, possessing that repose almost peculiar to

ecclesiastical architecture. But the term ornamental brickwork is so closely associated in these days with the idea of *form*, that we are accustomed to exclude from the meaning of that term all brick designs characterized by an absence of projection.

We know no better samples of red brickwork than St. Paul's Schools, and the City Guilds Technical Institute, Kensington; and the Midland Hotel, St. Pancras Station.

BRICKS.

In dealing with brickwork it is necessary that something should be said about bricks, though it is not intended to go into the chemical properties or other scientific matters connected with them, as we are presumably writing for persons in or connected with the trade of a bricklayer, but will just take a passing glance at the bricks commonly used in and about London, and state the purposes for which they are best adapted.

Stock bricks are divided into "picked" stocks (picked for colour and hardness), "washed" stocks, "grizzles," "place," and "shuffs." "Shuffs" are worthless, "place" are little better; "grizzles" are those bricks which have a good face or end with the other face or end underburnt, and similar in appearance to "place," which are of a reddish colour. "Picked" are those which are suitable for good exterior facing. "Washed" stocks, on account of their softness, are fit only for interior facing. The best stock

bricks for general facing purposes are those called "shippers," which, as their name implies, are sorted for shipping.

Malms are a superior kind of stock bricks, made of washed clay and chalk, and are used for superior facing and for "cutting" purposes, but are not suitable for "gauged-work" on account of the numerous small air-cells contained in the bricks, which make it impossible to rub them up to an arris, which is indispensable to good setting.

Of red building bricks there are a great variety in the London market, the best of which for colour and weathering properties are Fareham reds, though rather irregular in shape. St. Thomas's Hospital, and the Nurses' Training Home, Queen Anne's Gate, St. James's Park, are faced with these. Sometimes they are rubbed down to obtain true faces; but this should be avoided for the sake of preserving the deep red colour, which constitutes the beauty of these bricks. Fareham rubbers for "gauged-work" also stand first in quality, though they are not extensively used, as they are dearer than the other varieties in the market.

Next in quality come the Berkshire Builders and T. L. B. Rubbers, made by T. Lawrance, Bracknell, Berks. The Teynham bricks, stamped G. Richardson, Teynham, are good bricks, possessing in a large degree the qualities that recommend the Farehams, and with the additional advantage of a fairly good shape. Gault bricks



are much used for facing; they are much harder than stocks, and also dearer. Of white bricks Suffolks are the very best. They are a close, firm brick, suitable for first-class facing, either exterior or interior, or for "gauged-work." They are of a soft nature, but harden very much by exposure to the action of the atmosphere.

A very nice piece of work—three-light geometrical windows—executed in these bricks, and designed by Messrs. H. Saxon Snell and Sons, 22, Southampton Buildings, W.C., may be seen in the chapel attached to the Rackham Street Infirmary, Notting Hill, W. Staffordshire blue bricks are the most suitable for external bases, plinths, and dwarf-walls for palisading, or wherever there is much traffic.

Enamelled bricks are now very extensively used instead of tiles; they can be obtained in various colours, and are suitable for facing dairies, &c., and areas where reflected or borrowed light is required. They are obtainable in double headers,



Fig. 8.

viz. two ends enamelled for 9-inch walls, and double stretchers for $4\frac{1}{2}$ -inch walls, single headers and stretchers for facing, and bullnose and chamfered bricks

(Fig. 8) for jambs or reveals. The best kind are those bearing the stamp, "Cliff, Wortley, Leeds."

Firebricks should be used for all places exposed to the action of fire or intense heat. They are made of fireclay, and should be set with close joints in a mortar made of the same material,

wetting the bricks before setting them. The mortar under the action of the fire will vitrify, and form one body with the bricks. In lining boiler furnaces, &c., bricklayers frequently use fireclay only with that portion of the work that will be subjected to the flame, but it may be set down as a rule that wherever it is necessary to use firebricks, it is also necessary to use *fireclay* to bed them in. Nevertheless, when it is not readily obtainable, plaster of Paris and sand may be used as a very good substitute for small jobs, but on no account should cement be used, for being non-elastic it will fracture under the action of intense heat. Stourbridge bricks are much used as the best kind of ordinary fire-bricks, but Dr. Siemens has shown the Dinas firebricks to be the best, and to be capable of resisting the temperature of $4,000^{\circ}$ to $5,000^{\circ}$ Fahr.*

CHARACTERISTICS OF GOOD BRICKS.

Soundness, freedom from flaws, cracks, or stones of any kind. They should contain no lumps of lime or limestone, however small; should be regular in shape and uniform in size, their length exceeding twice their breadth by the thickness of a mortar joint. They should not absorb at most more water than is equal to one-sixth of their dry weight. They should be hard, and burnt so thoroughly that there is incipient vitrification all through the brick. When struck together they should yield a clear metallic ring. (This last-

* Dr. Siemens' "Chemical Society," 7th May, 1868.

mentioned characteristic belongs more to stocks and the harder kind of bricks.) Their texture should be homogeneous and compact. They should be regular in colour, with their arrises square, sharp, and well-defined. Pressed bricks, such as those from the midland counties and Ruabon, are almost non-absorbent, and for all practical purposes impervious to water. The nearer bricks approach to imperviousness the better will they be.

The following is an analysis of the clay worked by Messrs. Monk, Newell, and Bryon—Ruabon—

Moisture	1·54
Combined water	3·54
Silica	63·00
Alumina	18·0
Sesquioxide of iron	6·70
Protioxide of iron	1·95
Potash	2·37
Soda	3·10
	<hr/>
	100·20

Bricks and terra-cotta, manufactured from this clay, may be seen at the Northern Hospital, Winchmore Hill, London, now in course of erection by Messrs. Wall Brothers, of London.

BOND OF BRICKWORK.

We will now enter into what might be termed the scientific part of bricklaying, and it will not be out of place to repeat what Smeaton wrote half a century ago with reference to this subject, and which is equally true to-day: "As the art of bricklaying is generally supposed to be so simple as to require little or no attention, it

will be necessary to remove this false impression by a somewhat particular detail of the facts which relate to it. There are many persons, and even some workmen, who suppose that nothing more is required than that the bricks should be properly bedded and the work level and perpendicular. But the workman who would attain perfection in his business should acquaint himself with the different arrangements made use of in placing [bonding] the bricks, so that one part of the work shall strengthen another, and thus prevent one portion from a greater liability to give way than another."

So much for the statement of an eminent engineer, than whom none knew better the value of bonding, as evidenced in the old Eddystone Lighthouse, which was so thoroughly bonded, one stone into another, and each into the whole, that nothing but the wearing away of the rock upon which it stood led (or was likely to lead) to its demolition.

OLD ENGLISH BOND.

Old English bond consists of alternate courses of headers and stretchers, while Flemish bond consists of alternate headers and stretchers in each course. Old English is the only *true* bond, the other bonds (and there are several) being merely arrangements to please the eye. Gwilt, referring to bond, remarks, in his "Encyclopedia of Architecture," that "previous to the reign of William and Mary all the brick buildings in the island were constructed in what is called English bond; and subsequent to the reign in question,

when in buildings as in many other cases Dutch fashions were introduced, we regret to say much to the injury of our houses' strength, the workmen have become so infatuated with what is called Flemish bond that it is difficult to drive them out of it. To the introduction of the latter has been attributed (in many cases with justice) the splitting of walls into two thicknesses; to prevent which expedients have been adopted which would be altogether unnecessary if a return to the general use of English bond could be established."

BOND OF FOOTINGS AND WALLS.

The Metropolitan Building Act requires that the footings of all walls shall not be less than twice the thickness of the superincumbent wall, or, as bricklayers call it, "the neat work."

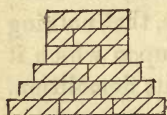


Fig. 9.

Fig. 9 represents the footing for a brick-and-a-half wall. A two-brick wall would require a four-

brick footing, and so on, according to the size of the wall, setting back $2\frac{1}{4}$ inches on each course of footings until the wall be brought into its proper size. Where a "bat" occurs in the footings, as



Fig. 10.

in the second course, it should always be kept in the centre. Fig. 10 shows in elevation the footings and three courses of a 14-inch wall. It will be

seen that the "closer" is not used until the

setting out of the bond for the "neat work." Figs. 11 and 12 are the plans of two successive courses of a one-and-a-half brick wall, showing the sectional bond. It will be seen by this that there are no two joints in the wall immediately one above the other, but that in the direction of the length of the wall there is a lap or bond of $2\frac{1}{4}$ inches of each brick over the two immediately below it in the next course, and a lap of $4\frac{1}{2}$ inches in the width of the wall. This result is obtained by running the transverse joints right through the

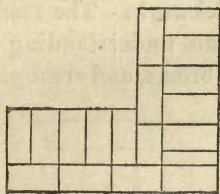


Fig. 11.

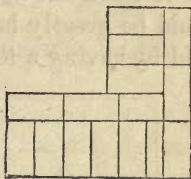


Fig. 12.

wall from one side to the other. A simple principle, but seldom carried out even by bricklayers.

The method in general practice is shown in Figs. 13 and 14. It will be seen that the transverse or "cross" joints do not run through the wall, but that the ends of the stretchers come in the middle of the headers, consequently the cross joints in the middle $4\frac{1}{2}$ inches of the wall are one over the other from the bottom to the top of the wall. This is caused by showing full "stretchers," *a* and *b*, in the internal angle, instead of letting them pass $2\frac{1}{4}$ inches into the return

wall, as in Figs. 11 and 12. Many bricklayers insist upon showing a whole "*stretcher*" in the angle in all cases; but he who insists upon this has

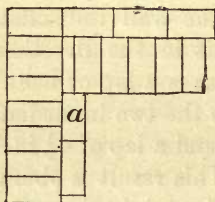


Fig. 13.

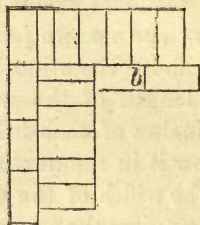


Fig. 14.

yet to learn the bond of brickwork. The reader would be greatly helped to an understanding of bond by having a few model bricks, and arranging



Fig. 15.



Fig. 16.

them as shown in these figures. Figs. 15 and 16 represent a straight jamb in a 14-inch wall. Here again, that the "cross" joints may run straight through the wall, it is necessary to introduce a

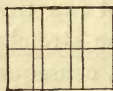


Fig. 17.

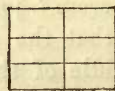


Fig. 18.

three-quarter "*stretcher*" *a*, and to omit the "*closer*" in the next course above. Figs. 17 and 18 are the plans of two consecutive courses of a

pier 14 inches on the face and 18 inches deep. The face bond is made up of two three-quarter "stretchers" on one course, and of three "headers" on the other. Figs. 19 and 20 are two courses of

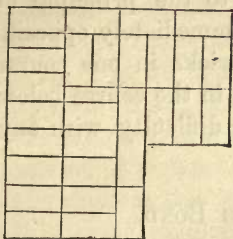


Fig. 19.

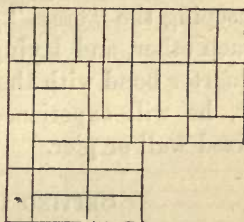


Fig. 20.

a wall two and a half bricks thick. In all walls of such a size as to take an odd half brick (two bricks and a half, three bricks and a half, &c.), the "stretcher" is always laid on the outside face in one course and on the inside face in the next course.

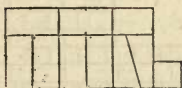


Fig. 21.

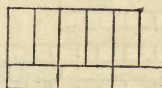


Fig. 22.

Figs. 21 and 22 show the "king closer," which in practice, owing to the trouble of cutting and the probability of breaking in the cutting, is seldom used. In this case two bricks are cut in their whole length from $2\frac{1}{4}$ inches to $4\frac{1}{2}$ inches, but it is more frequently cut out of one brick, as in Fig. 23, and an adjoining "bat" is cut to fit it.



Fig. 23.

A great many instances of bond in different

sized walls and piers might be given, but as a thorough knowledge of "bonding" can be obtained only by practice, we will not multiply examples.

If the bricklayer adhere to the principle of keeping the "cross" joints immediately opposite each other, and laying the bricks in one course quarter bond with the bricks in the course below it, he will experience little difficulty with any sized wall or pier.

SETTING OUT THE BOND.

The chief thing in connection with brickwork is setting out the bond, for which a good bricklayer should be selected. This will be more readily conceded when we consider the strains to which a building is subject. The bond should be

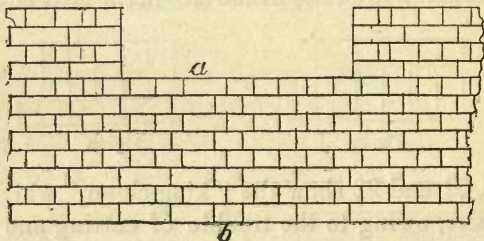


Fig. 24.

set out at least one course below the ground line, and the positions of doors, windows, panels, or large apertures taken off the drawings. This is best done in a stretching course, setting a "perpend" for every reveal or jamb, and working the

“broken bond” under each window, or other aperture, as the case may be, as in Fig 24, *a* and *b*. Reveals and jambs in point of bond should be treated as “quoins.” Where a base occurs the “bond” should be so arranged that a whole brick will work in the internal angle above the plinth.

In Fig. 25 (plan and elevation) we have a $2\frac{1}{4}$ -inch plinth; a “perpend” or vertical joint in the stretching course is

started $6\frac{3}{4}$ inches from the angle at the base; this joint “plumbed” up will be 9 inches, or a brick, from the angle above the plinth, and work proper or conventional “bond.” In many cases the base is treated by bricklayers as if it were a detached part of the building,

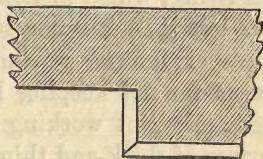
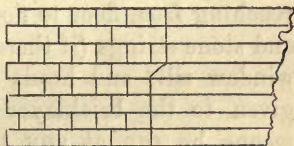


Fig. 25.

and the consequence is that “closers” are to be seen in the internal angles of many good buildings where whole bricks should be found. Such things, though small in themselves, go a long way to make up or to detract from the general effect and appearance of brickwork.

“Broken Bond” is the result of badly proportioned piers; thus, in a pier 3 feet $2\frac{1}{2}$ inches long, the bricklayer would have to work four bricks and a quarter, but to do away with the quarter or “closer,” a header and a three-quarter

“stretcher” are substituted for a “stretcher” and the “closer,” the three-quarter and “header” making up the “broken bond,” and are kept as near as possible in the middle of the pier.

The work once above the ground, the building should be levelled all round, and a piece of hoop-iron fixed in a joint at each corner or angle to gauge or measure from, taking care that they are all in the same level course. A “gauge-rod,” reaching from floor to floor, with all the courses and stone strings (if there be any) and heights of window sills and heads marked on it, should be given to the bricklayer to work to, by which means he can at any time see how his work is rising, which in London should not exceed nor be less than four courses to a foot; and the careless or inferior workman will then have no excuse for not keeping his work level and to the gauge. Not working to a gauge-rod is the chief cause of thick and thin joints, though any competent workman with a 2-foot rule should be able to keep his work right. The bricks in building should be wetted, but not to saturation, and the mortar of such a consistency that the “cross” joints between the bricks can be drawn up as the bricks are laid; any open or partially filled joints can then be filled by “flushing,” which is to be preferred to “grouting,” and should be done on every course.

HEADING BOND

is the name given to that arrangement in which the bricks are laid all “headers.” This bond is used

in circular and curved walls of a short radius, and in round chimney stacks, so as to keep the wall within the "sweep," or arc, for if "stretchers" be used, every 9 inches of the wall will be a straight line, and when built will consist of projections and hollows, and will be in that state described by bricklayers as "*hatching and grinning*." Heading bond should never be used on straight walls or where it can be avoided, as very little longitudinal strength is obtained, as will be seen by refer-

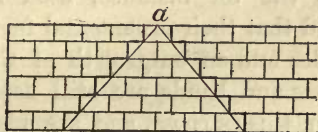


Fig. 26.



Fig. 27.

ence to Figs. 26 and 27, showing the angles of strain in two walls, one in heading bond and the other in English. The thick lines show the direction a fracture would take in the event of a settlement. They also show the space over which any given weight resting on either *a* or *b* would be distributed; and this idea leads us to the consideration of the use of stone templates and strings in connection with brickwork.

TEMPLATES AND STRINGS

Templates under girders, principals, beams, &c., should always be of York, never of Portland or any similar stone, and should be at least 14 inches long—18 inches would be better, but the length must be regulated by the weight which it has to carry. There is little doubt that “string courses” in the shape of a flush band were first introduced to impart strength to walls whose component parts were of diminutive dimensions (the Roman tile for instance, used in Roman walling), and that their ornamental feature was a secondary idea and an outgrowth of the former. String courses and bands are still used very extensively for this purpose, and are placed generally at the floor line, the window sill level, or the window head or springing line, and in some buildings in each and all of these positions.

BATS.

A consideration of the previous remarks will have illustrated the evil attending the use of “bats.” The greatest evil in connection with them is that workmen when walling, instead of fairly distributing them amongst the whole bricks, generally allow them to accumulate on the scaffold, and when they have a quantity put them in the wall all together, much to its injury. Good work may be done with a fair proportion of “bats” if they be used with discretion; and it is only fair to the builder that he be allowed to use the bats made on the job.

FLEMISH BOND.

Having already pronounced upon the merits of this bond and given the opinion of an eminent authority (Gwilt), little remains to be said on this subject beyond explaining a few examples in different sized walls and piers.

Figs. 28 and 29 show a 14-inch wall with a

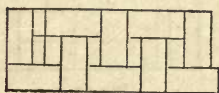


Fig. 28.



Fig. 29.

straight jamb, both sides Flemish bond, showing the way such a wall is generally bonded in practice. The rule laid down to keep the "cross" joints straight through the wall is departed from in this example, consequently the joints in the middle of the wall are one over the other in the entire height of the wall. The proper method is shown in Figs. 30 and 31, in which the "closer"

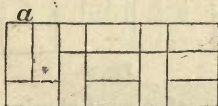


Fig. 30.

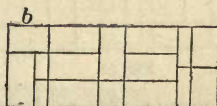


Fig. 31.

is dispensed with, and two "headers," *a*, in one course and a three-quarter "stretcher," *b*, in the other are used. A heading and stretching course are obtained by laying whole headers on one face and "snapped headers" on the other. A still better bond would be obtained by laying the

headers on each face, alternately "header" and "snap;" but to prevent all "snaps" coming over each other and all whole headers over each other they (the "snap headers" and the whole "headers") should be alternated in the height as well as on the level.

Figs. 32 and 33, the same wall, with the face

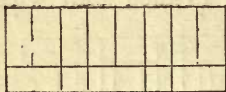


Fig. 32.

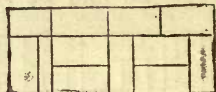


Fig. 33.

in Flemish and the back in English bond. A good strong wall can be obtained in this way, and where the inside has to be plastered it should always be so built.

Figs. 34 and 35, a two-brick wall, Flemish bond both sides. By snapping the headers in



Fig. 34.

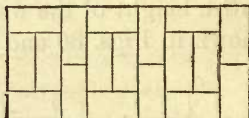


Fig. 35.

one course, 34, and putting them whole in the other, 35, a heading and a stretching course are obtained, which gives a much better bond through the wall than if all whole headers were used. Fig. 36, a quoin in isometric projection, showing the internal and external angle, and a perfect bond as far as obtainable in Flemish bonding with the inside face built in Old English bond. Fig. 37 gives

the bond of a two-and-a-half brick pier projecting from a wall. At *a* is shown a broken bond—two “stretchers” in one course and three “headers”

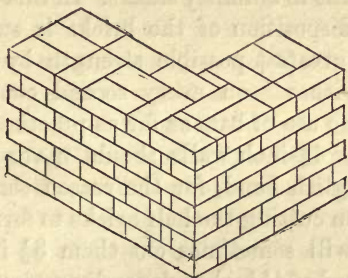


Fig. 36.

in the next course above them, which frequently occurs, and is the only legitimate “broken” bond in Flemish. Where a three-quarter “stretcher”



Fig. 37.

occurs as “broken” bond, it can be obviated or done away with by “reversing” the bond on one end of the pier or wall. Thus for a “stretcher” substitute a “header” and “closer.”

VARIOUS BONDS.

Chimney bond is a term applied only to $4\frac{1}{2}$ -inch external walls to chimney stacks. In this arrangement the disposition of the bricks is such as to obtain the greatest possible strength by bonding in the "withes" on every second course, and avoiding the use of bats as far as practicable.

Stacks of $4\frac{1}{2}$ -inch walls should never be built in Old English bond, for the reason that bricklayers, when cutting the half bricks to form "snap headers," will sometimes cut them $3\frac{1}{2}$ inches in depth instead of $4\frac{1}{2}$ inches, depending upon the pargetting or mortar to make up the thickness of the wall, which when the flue comes into use will shrink and crack, and falling away from the brickwork leave a stack, in many cases, built partly of closers. English bond is also objectionable on account of the numerous bats. Another practice in $4\frac{1}{2}$ -inch stack building, and which cannot be too severely condemned, is that of "buttering" the cross joints with the point of the trowel; or, in plainer words, putting a mortar joint between the ends of the bricks, extending in about 1 inch from the face, the remaining $3\frac{1}{2}$ inches being left open, excepting what little may be filled up in the process of pargetting.

We believe this practice, together with that of plugging into $4\frac{1}{2}$ -inch chimney walls for fixing skirtings, to be a fruitful source of many fires, with accounts of which we are occasionally startled. The mortar or cement joints should be put *right*

through the width of the bricks, and drawn up solid and tight. Stacks with $4\frac{1}{2}$ -inch walls may often be built with advantage in Flemish bond; but the main thing to be attained is strength, which is to be obtained only by bonding in the "withes" or divisions between the flues. Another reason the author would advance in objection to $4\frac{1}{2}$ -inch walls for chimney stacks is that plumbers, in "flashing" round the base, cut out the joints for the purpose of turning in the lead; and when wedging the same, thoughtless of the power exerted by the wedge, often break the bond of adhesion between the mortar and the course above the "flashing," leaving the stack in this condition to withstand a wind pressure of from 40 to 50 lbs. on the square foot during a hurricane, often resulting in a coroner's inquest. Zinc "soakers" may be used with much advantage in connection with stacks built with $4\frac{1}{2}$ inch walls, and the angles formed by the junction of the stack and the slating filled in with a small cement fillet, triangular in section, making a perfectly sound and water-tight job, doing away with the necessity of flashings, and preventing the evils that sometimes attend them.

English garden-wall bond consists of three courses of "stretchers" to one course of "headers." This bond may be said to have grown into disuse, excepting in the north of England, where five courses of "stretchers" to one course of "headers" are frequently used in general building. Flemish garden-wall bond consists of three "stretchers"

to one "header" in every course, as in Fig. 38. Garden-wall bond is used only, as its name implies, for 9-inch garden walls that have to be kept fair

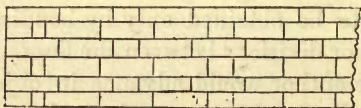


Fig. 38.

or smooth on both sides. The bricks vary most in their lengths; the more "headers" that are put through the wall will, therefore, add to the difficulty of keeping it straight.

HERRING-BONE BOND.

Figs. 39 and 40 represent a panel filled in with bricks laid "herring-bone." The former is gene-



Fig. 39.



Fig. 40.

rally the method used in paving, where the bricks are laid on their beds, $4\frac{1}{2}$ by 9 inches, in sand, and "grouted" up with cement or mortar. The latter is used for filling in panels under windows and for tympana of arches, and are laid four

courses to the foot. When a large area of paving has to be done in this way, the simplest way will be to work from a centre line, and lay the middle course first and at an angle of 45 degrees, the other courses will then follow, and the points may be kept right by means of a line drawn parallel to the centre line.

In a panel, the first brick starting from the corner should be set to a small set square, forming a right angle and two angles of 45 degrees, and measuring from the base to the apex 3 inches, or whatever the bricks will work.

DUTCH BOND.

Fig. 41 is an arrangement called Dutch bond. It is a modification of English bond, the "closer"

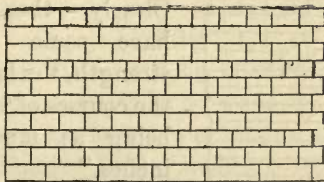


Fig. 41.

being omitted and a three-quarter "stretcher" used on the "quoin." In every third stretching course a "Flemish header" is introduced next to the "quoin" brick, by which means the "stretchers" in that course are pushed forward, and overlap the "stretchers" below $4\frac{1}{2}$ inches, instead of being "plumb" over them as in other

bonds. The advantage of this bond is that additional strength is imparted to the wall in the direction of its length, and that without diminishing its transverse strength. A writer in the *Builder*, from which Fig. 41 is taken, speaking of this subject says : " As regards construction in common English and Flemish bonds, no greater tie in the direction of the wall is obtained than $2\frac{1}{4}$ inches which one brick overlaps another. If, therefore, a fracture takes place, the crack runs down the wall, following the joint with only that small deviation from a perpendicular line ; but by the Dutch method a crack would have to follow $4\frac{1}{2}$ inches to the right or left in the courses

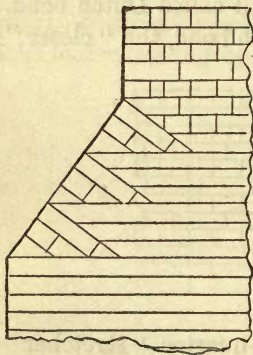


Fig. 42.

containing the 'Flemish header,' or else break through the bricks. Clearly, therefore, we have some additional strength, the lap between the courses of 'stretchers' being as much as $4\frac{1}{2}$ inches."

The adjoining Fig. 42 shows the way in which buttresses and chimney stacks are reduced. They are generally "tumbled in" at an angle of about 60 or 70 degrees. The beds of the bricks should always be at right angles to the "tumbling in." The bond on the "battering" jamb will be the same as on the upright jamb below.

“KEEPING THE PERPENDS.”

Architects usually specify that the “perpend” shall be kept, or, in other words, the vertical joints are to fall in plumb lines from top to bottom. Owing to the difference in the sizes of bricks, this cannot be done with bricks as they come to hand; they must be sorted to a length, or cut where necessary, by the bricklayer as he proceeds with his work. This would add to the cost of the work, and, as cost has to be considered in most buildings, it is seldom done. But if the bricklayer carry up a plumb line in the middle of large piers, and work his bricks between that and the plumb reveals or jambs, he will be able to keep his “perpend” tolerably regular. The “closers” should be cut to a $2\frac{1}{4}$ -inch gauge.

TOOTHINGS.

Toothings should not be allowed in a building where they can possibly be avoided; they are a source of weakness, and very often a disfigurement to a building. When building into toothings, the bricklayer seldom takes the time or trouble to make solid work; and where they have been can very often be traced in buildings that have been up but a short time by the pointing having fallen out right down the line of toothings. This is caused in frosty weather, by the expansion of moisture which has got into the hollow parts of the toothings, forcing the pointing from the brickwork, to be washed off by the first heavy

rainfall. Where toothings are unavoidable, they should not be carried up in a straight line from bottom to top, as they usually are, but should be stepped back every few courses, so that the new work may be bedded solidly here and there. When building new work into old, a chase is preferable to a tothing, as the new work is left free to settle. But in a front where new work has to be built into an old tothing there should be no mortar used in the tothing; the new work should be kept a trifle high above the old, and the joints of the tothing filled in after the building is up. Among the characteristics of good brickwork are solidity, perpendicularity, smoothness; the vertical joints carry a plumb line from top to bottom; the "cross" joints of the "stretchers" fall immediately in the centre of the "headers," and the bed joints are neither too thick nor too thin.

GROUTING.

"Grouting" is the practice of using mortar or cement in a semi-liquid state to fill up the open joints in the work, the result of careless or bad workmanship. In some works every course is "grouted" in; in others every four courses.

"Grouting" is not the best way to obtain solid walls, for the mortar being in a semi-fluid state, the excess water is absorbed into the bricks of which the work is composed, and, as a consequence, the "grouting" shrinks or subsides, leaving the joints or interstices only partially filled. A

better process is that of "*larrying-up*," which is, after having laid a course of bricks on each side or face of the wall, to put a proper amount of mortar in the wall, and by the addition of water, and the use of trowels, shovels, or a larry, to reduce it to such a consistency as to be able to swim in the bricks solidly. Even in this practice there is a subsidence or shrinkage of the mortar, with the same effect, though in a less degree, as described in "grouting." But the best and proper plan is undoubtedly that of putting up the joints solidly through each brick as it is laid, and having the mortar of such a consistency as to be able to draw the joints up solidly when filling in the middle of the wall.

FLUES.

Of the abominations of a bad building, bad flues are second only to bad drains. The causes of smoky flues are as follows. The sectional area of the flue is either too large or too small. Its sectional area is cramped, the "cramp" generally occurring in sharp bends, close to a floor, where the bricklayer has to make room for another fireplace. The flue is too short, or is not carried up high enough to be above some adjoining building or contiguous wall. There is too much air-space below the throat of the flue, or, in bricklayers' phraseology, the wing gatherings are not brought over fast enough. In considering the scientific principle of flues, we should remember that the properties of air in their action are very similar to

those of water. A stream with a straight smooth course flows swiftly and regularly, while one with a rugged winding course is full of eddies and whirls, and flows with a retarded velocity. So it is with flues. An unused flue contains a column of cold air in equilibrium with the surrounding air. This column of cold air must be rarefied or heated before a good draught can be obtained, when the denser air rushes in, pushing the lighter up. This will account for the fact that a flue never draws so well when the fire is first started as it does some little time after.

Where the flue is unnecessarily large, a larger volume of air has to be rarefied, and it also admits of a possible down draught, or in other words an ascending and a descending column, in consequence of the heated air not filling the flue. Where the flue is "cramped" somewhere in its length, the cause of smoking is that the smoke is checked in its ascent just where the "cramp" occurs, the smoke escaping with a retarded instead of an increasing velocity. Sharp bends have the same effect, though in a less degree, as "cramps." Yet it is a common thing to hear bricklayers advocating sharp bends in flues to increase their draught.

Every flue should be formed with sufficient bend to prevent the daylight and rain falling upon the fire.

Where a flue terminates below an adjoining wall, it will often smoke in consequence of a down draught, caused by the wind striking against the wall and in its rebound passing

down the flue, or at least obstructing for a time the passage of the smoke from the flue, which in effect is similar to a down draught. Where the throat of the flue is formed high up above the chimney bar there is a large volume of cold air collected which has to be heated or rarefied to get a proper draught ; until this takes place the smoke is obstructed in its ascent, and driven back into the room.

To cure these evils, innumerable contrivances have been invented, of various forms and different degrees of ugliness, and it is almost rare to see a house in the metropolis that is not surmounted with one or more of these articles, each advertised as a panacea for smoky flues. These so-called remedies are (with the exception of the "blower") always applied to the top of the flue, when in fact the remedy is generally required at the bottom or somewhere in the length of the flue. We would give the following advice for flue building. Form the throat of the flue as low down as possible, and let the sectional area be the same throughout its entire length, avoiding all bends beyond what is necessary to hide light. Where bends cannot be avoided let them be as easy as possible, and carry the flue well up above contiguous structures, and let it be pargetted smoothly inside. In building flues "coring holes," 12 × 14 inches, should be left out on every floor, or at least where every bend occurs, and a piece of board put in to catch the mortar and brick rubbish that fall while in erection. By



this method the flues may be easily "cored" or cleared without the aid of a chimney sweep. Flues for dwelling-houses are generally for registers, 9×14 inches, and for kitchens 14×14 inches.

Fig. 43 is the plan of a fireplace and flue for a register stove, which we insert by permission of the originator, H. Saxon Snell, Esq., F.R.I.B.A.

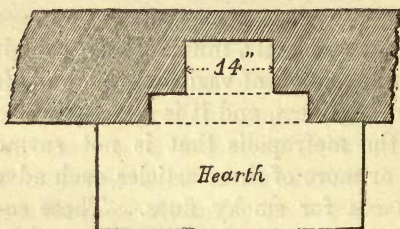


Fig. 43.

The peculiarity and advantage of this fireplace is that the sectional area or throat of the flue commences immediately on the chimney bar, doing away with the necessity of wing gatherings and the possibility of cold air collecting round the base of the flue. This for its economy of construction and efficiency of action recommends itself for general use.

All chimney stacks from the part where they pass through a roof, or from the point where they separate from a wall with which they have been in junction, to their tops, should be built in cement and sand instead of with lime mortar.

Where several flues are grouped together in

one stack, instead of dividing them with the usual $4\frac{1}{2}$ -inch brick "withes," Boyd's flue-plates (iron plates $\frac{1}{8}$ inch thick, and about 12 inches square, fitting into each other with a tongued and grooved joint, and built into the sides of the stack) are often introduced to economise space.

To ensure that flues shall have the same sectional area in their entirety, they are sometimes built round a wooden section-box, open at both ends and with a wooden "strap" to take hold of, that the box may be pulled up from time to time as the work progresses. The box is placed in the space intended to be occupied by the flue, and the bricks carefully laid with full joints against the box, which is drawn up about every two or three feet. In some cases the pargetting is dispensed with, and the joints struck instead. Good flues are undoubtedly obtained in this way. The same end is obtained by the use of Doulton's terra-cotta flue-pipes; but when built in small detached piers (as they sometimes are), they prove a source of weakness by interfering with the bond of the work. Where they are grouped in stacks there should be a space of $4\frac{1}{2}$ inches between each pipe, to admit of bonding the stack in the direction of its width.

SECTION II.

ARCHES IN GENERAL.

ARCHES.

ARCHES are of various kinds, but those which the bricklayer has to deal with are either circular, segmental, scheme, elliptic, or Gothic. To the young operative, and in many cases to the aged workman, they are veiled in mystery, though a little application and determination to understand them would soon make them clear to the operative who would be master of his trade. Time was when the arch-cutter would box himself up and carefully tack strips over the chinks between the boards that prying eyes might not penetrate into his cutting-shed and discover the craft by which he held himself superior to his fellow-workmen. This jealousy and exclusiveness is still alive, though it is being slowly trampled under by means of the flood of light that is spread abroad, and is still spreading, from technical classes and technical publications. If the young workman will but set to work in earnest, there is every facility to acquire technical knowledge, and to make himself, as a workman, superior to those who have gone before, and who,

“By geometric scale,
Did gauge the size of pots of ale.”

Let him but catch that spirit breathed forth in

Longfellow's lines to Strasburg Cathedral, and success will surely be his :—

“ A great master of his craft,
Edwin von Steinbach ; but not he alone,
For many generations labour'd with him.
Children that came to see these saints in stone,
As day by day out of the blocks they rose,
Grew old and died, and still the work went on,
And on, and on, and is not yet completed.
The architect
Built his great heart into these sculptured stones,
And with him toil'd his children, and their lives
Were builded with his own into these walls,
As offerings to God.”

The word *arch* implies an arrangement of bricks or other material in which all its parts—we might with equal propriety say particles—are in equilibrium ; or, in other words, that the pressure or thrust to which it is subjected is transmitted from one course to the other, and distributed throughout the whole of the arch, each course or voussoir taking its share. Every bricklayer who has turned an arch will have noticed that this condition is not obtained by simply turning the arch on its centre and keying it in, the tendency being for the arch, by reason of its own weight, to spread out at the springing, or if this be prevented to buckle up at the haunches, to prevent which and bring about equilibrium, calculations have to be made so as to apportion the weight at the haunches to resist or counteract the thrust from the crown. Such mathematicians as Dr. Hooke, Huygens, Leibnitz, and many others, devoted much time and attention to the solution of the principle of the arch under the

name of the *catenary curve* (Latin *catena*, a chain); and the conclusion *they* arrived at was, that the true shape of an arch is that into which a chain would arrange itself if freely suspended from two points whose distance apart is equal to the span of the intended arch. We have mentioned these things because, considering the way in which arches are often *thrown* together, it is well that the artisan should know there is a principle involved in their construction.

RELIEVING ARCHES.

Relieving arches should be turned over all lintols where practicable, and should spring clear of their ends. They should not be built, as they generally are, solid on the brick "core," whereby the weight of the wall above is transmitted from the arch to the "core," from the "core" to the lintol, and from the lintol to the frame, very often to the great injury of the latter; but should be built at least $\frac{3}{4}$ inch clear of the "core." This can be done by putting a layer of sand $\frac{3}{4}$ inch thick on the core, and raking it out with a trowel or piece of hoop iron when the arch is turned, that it may take its own bearing. They should be turned in compo.

The above remarks apply to where the window and door frames are built into the brickwork during erection; and more particularly to arches intended to relieve free-stone rectangular door and window heads. It is not an uncommon thing to see such heads fractured right through their

depth in about the middle of the openings which they span, and kept from falling only by the weight of brickwork upon their ends ; though the architect has been careful to provide against superincumbent weight by the use of relieving arches, but which, through inexperience or want of judgment, or some other cause, have been built upon a solid "core."

PLAIN ARCHES.

All arches put in with bricks as they come from the brickfield come under the term plain arches, and are built in concentric rings of $4\frac{1}{2}$ inches laid as "headers" on edge, instead of bonding by "stretchers," to avoid the large joints that would unavoidably occur at the extrados, thereby decreasing the strength of the arch unless it were built with cement, or a strong hydraulic mortar, as *lias*.

THE SKEW OR OBLIQUE ARCH.

This arch is used in the construction of bridges over roads or waterways where the bridge is not at right angles to the road passing under it.

Two very remarkable arches of this kind may be seen on the Metropolitan District Railway at Brondesbury, and which the writer believes to be the only bridges so constructed. Of these we will speak hereafter.

To set out and understand drawings of the skew arch, a knowledge of solid or descriptive geometry is indispensable ; but as the setting out

is generally performed by the engineer or inspector of works, we will confine our remarks to that portion of the work which properly belongs to the operative bricklayer. $A B C D$, Fig. 44,

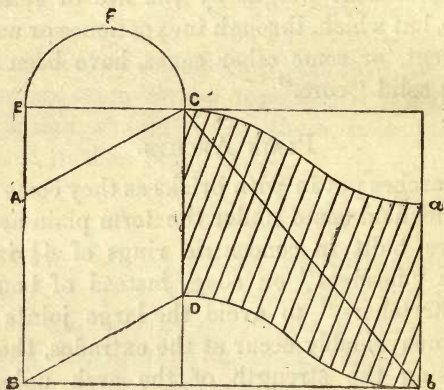


Fig. 44.

represents the plan of a skew arch of which $E F C$ would be a section cut square with the abutments. $E C A$ is called the angle of skew, for it shows how much out of square the face of the arch is with the road. $a c$ is the face of the arch, and as the "bed" joints (called by engineers "coursing" joints) start square from the face, they must run in a diagonal direction across the centre, as seen in $c D a b$, which is a development of the soffit of the arch. To make this clear, we will suppose the courses to be pencilled on the centre, and a sheet of white paper folded round the centre and rubbed until the pencil marks be transferred to the paper. If the paper—

fastened at $c D$, the abutment line—be now unfolded from the centre and spread out on a level surface as in Fig. 44, we shall have a development of the soffit of the arch. $c a$ is the length of the line on the centre from c to A . $D b$ is the length of the line on the centre from D to B , and is

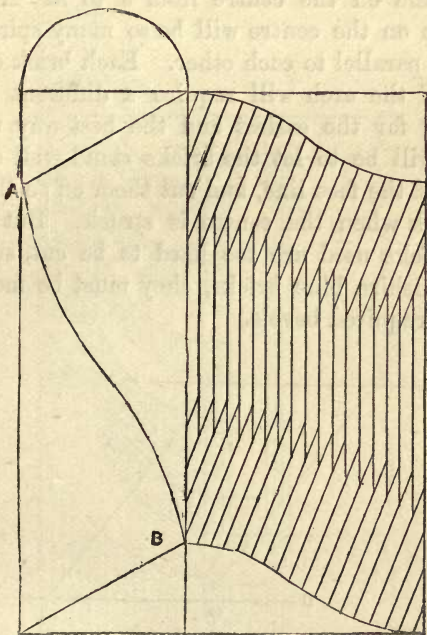


Fig. 45.

parallel with $c a$. $c b$ is the length of a line on the centre from c to B .

In long skew arches the bricks, instead of being laid on the skew all through the arch, are

arranged as in Fig. 45, where the skew courses are intersected by courses laid parallel with the abutments. The skew courses are marked on the centre by means of a "coursing mould," which should be supplied by the engineer or inspector in charge of the work. A B is the plan of a line on the centre from A to B. All the courses on the centre will be so many spirals or screws parallel to each other. Each brick on the face of the arch will require a different bevel, but by far the easiest and the best way to get these will be to let the bricks stand well out in front of the face line, and cut them off to the line of work when the centre is struck. But when the bricks used are too hard to be cut, such as Staffordshire blue bricks, they must be moulded to the required bevels.

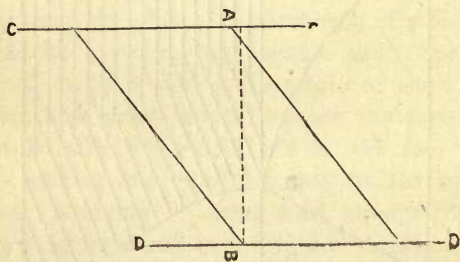


Fig. 46.

SKEW ARCH AT BRONDESBURY.

The remarkableness of this arch or skew is not alone in its construction, but in the angle that it makes with the roadway that it spans, the angle

being so acute as to cause the abutment line or skew-back of one side to fall *without* the abutment line of the other side. This is shown by the line A B at right angles to C C, D D, Fig. 46.

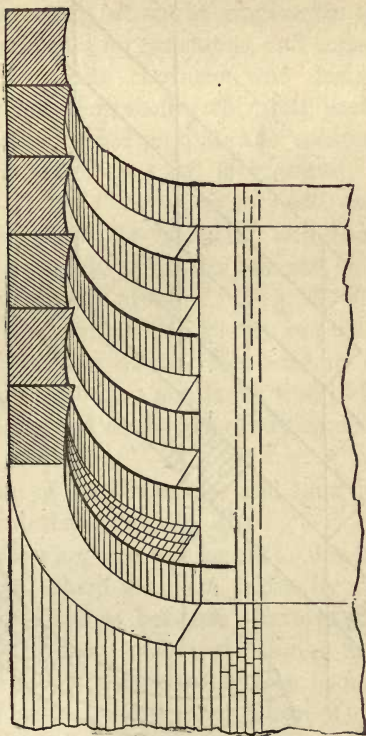


Fig. 47.

Let us imagine that across a given road we have to construct a bridge whose angle of skew

shall be equal to that on the accompanying

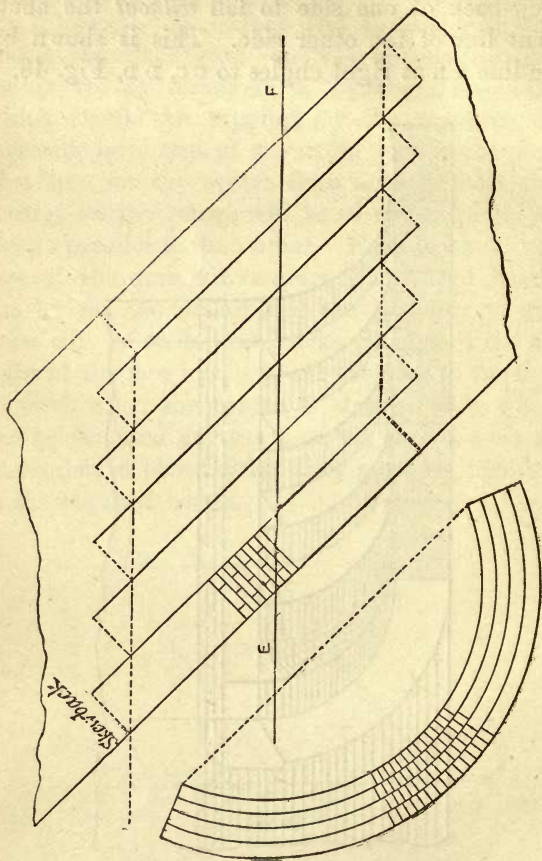


Fig. 48.

Fig. 49.

Fig. 46. It is clear that we cannot construct it on the principle of the ordinary skew arch, viz.

to take the courses (starting square with the face of the arch) as so many spirals across the centre, finding their abutment in the line $c c$, and as we have explained at page 50. An arch so constructed could not stand, for the lines of force, or thrust, acting at right angles to the abutments, would find no resistance, and consequently collapse. But the engineer who designed the bridge in question, seeing this, fell back on the principle that should regulate the construction of all arches where strength is required, that *the bed joints shall be in the line of radii, and on the soffit parallel with the abutment*, and thus in the simplest, yet most effective manner, solved the otherwise difficult problem. Fig. 47 shows the sectional elevation on the line $E F$ in plan, Fig. 48 the plan, and Fig. 49 the face arch in elevation of a bridge somewhat similar to that at Brondesbury, constructed in the same way, and involving the same principles.

The plan of the abutments and skew-backs are shown by dotted line (Fig. 48).

The following are approximate dimensions of this bridge, which we have taken by step measurement: distance between abutments, 45 feet; depth of bridge, measured along the abutment, 26 feet; rise of arch from cord line to crown of soffit, 20 feet; projection of one abutment beyond the other (D beyond A , for instance, Fig. 46), 36 feet. The arch is made up of twelve $4\frac{1}{2}$ -inch concentric rings of brickwork.

WATER CONDUIT.

Fig. 50, a section of a water conduit in Massachusetts, U.S.A., upon which the author was engaged as inspector of works, is worthy of notice, as showing the construction resorted to where a bad bottom occurs. In this case a large

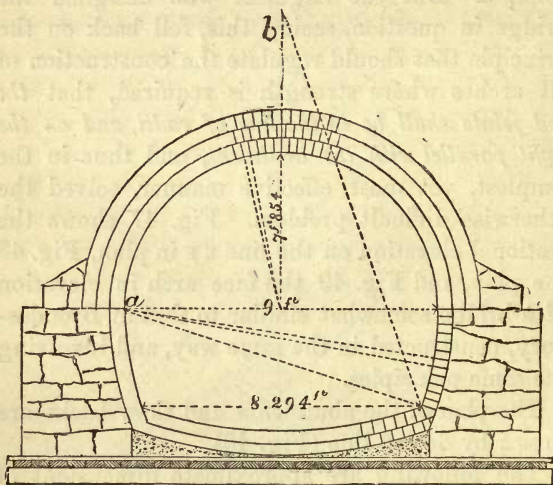


Fig. 50.

portion of the work (which was eighteen miles in length) ran through very swampy ground, a natural watercourse that drained a large tract of the adjacent country, and at times so great was the pressure of the water as to cause it to rise in a natural fountain 6 or 7 feet above the excavations. When this occurred, stones of sizes similar to those of which the retaining walls were

built were shot into the hole until the water subsided or found an easier outlet elsewhere. It was also necessary to keep pumps working night and day.

The bottom consisted of 6×6 inch transoms, 18 inches apart, to which were spiked 2-inch planks, and these in turn were covered with 1-inch boards, with joints properly broken, as in flooring. The invert, when the side walls were built, was formed with concrete ready to receive the brickwork. The whole of the work, including concrete, was built in Rosendale cement, manufactured in Rosendale, New York, from a stone found in that locality, which when manufactured is in colour very similar to Roman cement, but less quick in setting, and attaining a greater ultimate strength. It will be noticed that the sides of the invert are struck from the springing line *a*, and the bottom from *b*, and that to get the requisite skew-back for the top and bottom beds, a *purpose made* brick is introduced, whose beds are in the line of radii from *a* and *b*.

Sewers are constructed on the same principle as water conduits, with this difference, that while strength and sound work suffice for the latter, to these must be added smoothness for sewers, avoiding all "shoulders," "lips," protuberances, or other irregularities likely to increase friction, or in any way retard the velocity of the sewage. Where the flow is intermittent they are generally built egg-shaped, to minimise the frictional area.

GROINED VAULTING.

Brick groin-vaulting (a very neat sample of which may be seen at the entrance to Winchester Flats, Winchester Terrace, Chelsea Embankment) was at one time very much in practice, but moulded stone ribs finishing at the apex with a carved boss now generally take the places of the brick groins. Samples of this kind of work may be seen at St. Augustine's, Kilburn; St. John's, Auckland Road, Upper Norwood, and the red brick church adjoining the Croydon railway station, all designed in that style known as the thirteenth century, or Early English, by John L. Pearson, R.A. Some good Gothic vaulting in red brickwork may also be seen at the New Law Courts, London. In executing the groin the bricks must be cut so as to form a return on the intersecting arch or vault; but a proper bond, as in square angles, cannot always be obtained, for, instead of the bricks returning from right to left and from left to right every other course, it will be found necessary to sometimes return several courses in succession, all from one side, before getting what bricklayers would call "a tie." This is caused by the groin not getting away fast enough from an imaginary line drawn across the arch from E to G Fig. 51. It is also impossible to keep the perpends regular near the groin, but they should be kept as regular as practicable with a good bond on the groin.

Before the bricklayer can cut his bricks, the

centres must be placed in position, and the bricks can then be cut to fit the intersection, which they should very accurately, and when the centres are "struck" present clean and well-defined arrises. Fig. 51 is the plan of two semi-cylindrical vaults, intersecting in the groins E F

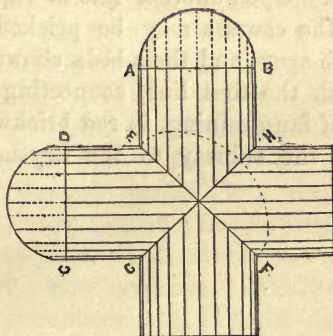


Fig. 51.

and G H. The curve formed by the groin is an ellipse shown in angular elevation on E F by dotted curve. Sections of the vaults are shown on A B and C D. Sometimes instead of being as here shown, the intersecting arches are Gothics, or one Gothic and the other semi-cylindrical; but if what we have written be understood no difficulty will present itself. In all such cases the bricklayer must space his centre out into courses, and turn the arches as any other arch, with the exception of the groin, which must be treated as described.

In Gothic vaulting, as described above, in

which the spaces between the stone springers are filled in with brickwork, the setting out of the courses is done by marking upward from the intersection, or springing of the ribs, an equal distance along the cross rib and the diagonal or converging rib, and connecting these two points with a line. Upon another line at right angles with this, the courses may be pricked in from springing to apex, and their beds shown by lines parallel with the first line, connecting the ribs. A sample of fan-groining, in red brickwork, may be seen at the subway to the Crystal Palace, Sydenham.

SECTION III.

GAUGED-WORK AND ARCH-CUTTING.

GAUGED WORK.

“Cutting” is divided into “axed work” and “gauged work.” In the former the bricks are finished with the Scotch, with just a rub or two round the rubbing stone to take off the irregularities of the beds, allowing $\frac{3}{16}$ of an inch joint for tuck-pointing. This work is intended to represent “gauged work,” and is supposed to be a trifle cheaper. “Gauged work” is a very superior kind of brickwork, executed in soft bricks set with a white putty joint, which should not exceed the thickness of a new sixpence. The bricks used are Fareham rubbers and T. L. B. rubbers for red work; and malm-cutters and sometimes white Suffolks for malm or stock work. Of red bricks Fareham Rubbers are the best; they are of a close, firm texture, will carry a sharp arris, and weather well; in colour they are cherry red. No. ones T. L. B.’s are good bricks, though less firm than Farehams, but of an even texture; they are divided by colour into two classes—cherry-red and orange tint. The orange is generally used, as they contrast well with the red building bricks, but will not carry so sharp an arris or weather so well as the darker bricks.

“Gauged work” is often objected to on the ground that it will not resist the action of the weather. This we can refute by our own ex-

perience, for we have taken out old "gauged" arches in malms that have withstood for forty years the acids contained in London smoke, and have shown no signs of decay or disintegration. We can cite another instance of the indurating properties of "gauged work" in white Suffolks when exposed to the action of the atmosphere. During the erection of the Rackham Street Marylebone Infirmary, some geometrical windows in these bricks had to be cleaned down some three or four months after erection. This process had to be done by rasping the face of the brickwork, and so hard had become the bricks that it was with difficulty that an impression could be made at all, the rasps sliding off the work and leaving a black mark! Bricks in this condition are said by bricklayers to be case-hardened.

This so-called case-hardening we attribute to the process of setting. In good setting the bricks are always soaked (not to saturation) in water, which in a building in course of erection always contains more or less lime in solution, which is taken up by the brick while soaking, and by exposure to the atmosphere becomes carbonised and forms a hard coating, as it were, upon the face of the brick. This case-hardening is also attributed to "the silicic acid in the clay acting upon the chalk so as to form some of it into a silicate of lime." Rubbers are purposely made much larger than the ordinary building bricks to allow for cutting and gauging them four courses to the foot, though as a rule they will not hold out or

bed more than $11\frac{1}{2}$ inches with close joints. T. L. B.'s as they come from the brickfield measure $10\frac{1}{2} \times 4\frac{7}{8} \times 3\frac{1}{8}$ inches.

They are also obtainable 12 inches long, but bricks this length are only required for Camber arches, or Gothic arches whose bed joints radiate from the centre, as in Figs. 57 and 58, in which so much of the brick is cut away to form the long bevels on the soffit and crown, that the ordinary sized bricks will not "hold out" to the required lengths, and have therefore to be lengthened, where necessary, by forming the long "stretchers" out of two three-quarter bricks (this will be best understood by examining a few actual camber arches); to obviate which, the 12 inch bricks are made.

SETTING.

In setting "gauged work" the joint is taken up by absorption by holding the bed of the brick in contact with the putty, which must have the proper consistency and be kept in a small putty-box made with a level top, so that the setter can rest or steady his arm upon it while "dipping" his brick. Before putting the brick in place, the putty is scraped off the middle of the "bed," that it may set or joint more evenly. The joint should not be touched after the brick is "bedded," but should be left full like a small bead. Stone lime should be used for setting, as chalk lime is not fit for out-door work. Axed-work is generally set with putty and cement. If the

work has to be carved deeply, it is best to build it all "headers," and "grout" it in solidly at back with Portland cement, that the bricks may not break up or get disturbed under the chisel of the carver.

A composition of whitening and patent knotting is more frequently used than lime-putty for bedding or setting work intended to be carved, and for ornamental key-blocks made up of two or more bricks. It will be found most convenient to put such keys or blocks together in the cutting-shed, and take them upon the building to be set as one piece of work. These remarks apply equally well to the niche hood in every particular. Gauged work intended to be bedded in the above composition should be quite free from moisture; but the bricks should not be placed round a fire for this purpose, as they often are, for by so doing they are made fragile and are easily broken. It is, therefore, very imperative that a good watertight cutting-shed be made for the bricklayer and another shed for the bricks.

DRAWING AND CUTTING ARCHES.

This forms a very important branch in the trade of the bricklayer, and a thorough knowledge of it is indispensable to the operative who would be master of his trade. In this section we will endeavour to make clear not only the setting out of the various arches, but how to take off the bevels and moulds, and apply them to arch-cutting.

An understanding of this will not be so difficult as may at first sight appear. The tools required

for this work are—the rubbing-stone (which should not exceed in diameter 14 inches), hammer, boaster, Scotch, scriber, and tin-saw. The scriber is a small tin saw, used for marking the beds and bevels on the bricks.

THE BULLS-EYE

Should have four keys, *a*, *b*, *c*, *d*, which when possible should be “stretchers;” but as this cannot always be done unless by very much reducing the size of the courses (technically called *voussoirs*), they are, therefore, frequently put in as in Fig. 52. The face mould for this arch is

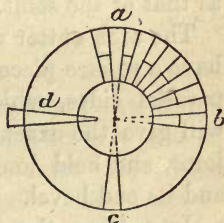


Fig. 52.

obtained by making a wooden pattern, as at *d*, on which the actual length of the brick is marked, and also its bevel, which is taken off the drawing by placing the stock of the bevel along the bed joint, and moving the blade until it coincides or is in line with the soffit of that particular brick whose bevel is required. All the courses have the same bevel and the same length. It is usual to have two moulds made, so as to trace or traverse the courses round the arch, to ensure that the key brick will come in rightly (though one mould and two parallel straight edges would do equally as well); for if the mould be in the least inaccurate, the inaccuracy will be transmitted to each brick, and this multiplied by the

number of courses in the arch (in this case 36), supposing the inaccuracy to be $\frac{1}{16}$ of an inch, would amount to $2\frac{1}{4}$ inches, in all probability the thickness of a course. Having proved the moulds, the pattern brick or soffit is marked lower down on the mould, that the brick when cut will be the thickness of a joint less than the brick shown on the setting out. The bevel of the thick end or *extrados*, as it is named, is the same as that of the soffit.

The arch cutter will find it most convenient to have a square piece of wood, $4\frac{1}{2}$ by 9 inches, with parallel sides, which held flush with the soffit will give the exact place and bevel of the cross joint, and held longwise the length of the brick and its end bevel.

In cutting, the first operation is to square the bed and face of the brick, after which the soffit is bevelled. The brick is then placed on a bedding board (a piece of slate or wood with a straight even surface) in the same position that it will have in the arch. The face mould is applied to the brick with the soffit mark against the soffit of the brick, and the scribe drawn along the top edge of the mould marks the wedge shape which the brick will have when finished. The back of the brick is marked in the same way, and is then finished with the boaster, Scotch, and rubbing stone.

SEMI AND SEGMENTAL ARCHES.

What has been said of the bulls-eye applies in every respect to the semi (Fig. 70) and the seg-

ment arch. To draw the curve (Fig. 53), the span and rise being given, bisect the line ab with cd ; join eb , and bisect this line with ih ; a line drawn from i through b will give the line of skewback. Taking the distance ib in the compass, with one leg fixed at i , the lower curve may be drawn from b to a . Nine inches measured along the skewback from b will give the point from which to draw the outer curve. On the outer curve, with cd as centre line, set out 3 inches, or whatever a brick with its joint will hold out, and with the mould (shown by dotted lines) trace the courses down to the skewback, increasing or diminishing the thickness of the brick as may be required by raising or lowering the mould.

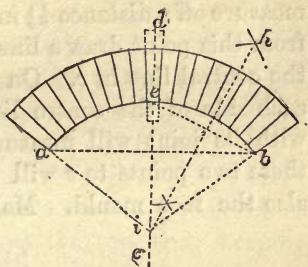


Fig. 53.

THE CAMBER ARCH.

Fig. 54 is a camber, 12 inches deep, in Flemish bond. The skewback is obtained by taking in the compass the distance ab , and from these points, with ab as radius, drawing the inverted Gothic; a line from c through b will be the line of skewback, or springing. To draw this arch when the skewback is given—say $4\frac{1}{2}$ inches—from the centre line set off the distance between the reveals from ab ; 12 inches above the springing,

draw the line $d e$, and from centre line along $d e$ measure off a distance $4\frac{1}{2}$ inches beyond the reveal; from this point draw a line through b , intersecting the central line in c . On $d e$ measure off $1\frac{1}{2}$ inch each side of the centre line, or whatever a brick with its joint will measure. Lines drawn from these two points to e will represent the key, and also the face mould. Make two moulds 9 inches

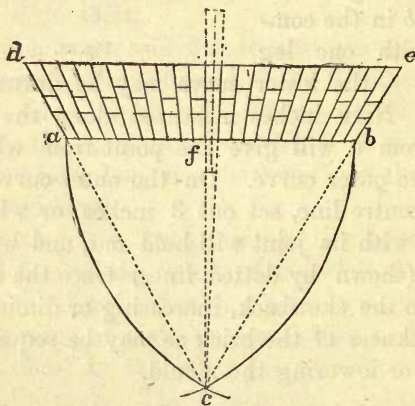


Fig 54.

($4\frac{1}{2}$ inches at each end) longer than the key. With the mould, shown by dotted lines, upon the key, on one of its edges, f , where $a b$ meets it, make a pencil mark. Put the other mould on top of this and transfer the mark to it. With the two moulds, keeping the pencil mark always on the line $a b$, traverse the courses in down to the skewback as described in the bulls-eye. Take off the bevels, starting from the skewback, and pencil

them upon the mould, 1, 2, 3, and so on, as shown in Fig. 55, *a*, which is a mould with the lengths and bevels of each course upon it. One-half only of the arch need be set out. The cross joints may be cut in the courses with the saw and parallel board, as previously described, always working from the soffit. For greater accuracy and distinctness, the bevels may be pencilled on the back of the mould, at the top end, keeping them some little distance apart, and numbering them as already described. The courses may be traversed in by working from the top line *d e*, instead of from the soffit, marking on the mould,

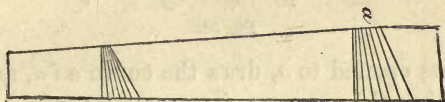


Fig. 55.

downward from the top mark, the length of each course. Having thoroughly understood the setting out and cutting of this arch, no difficulty will be experienced with any of the ordinary arches.

The soffit generally cambers $\frac{1}{8}$ of an inch to the foot.

The camber is not suited for large openings, or where any considerable weight has to be carried, as it is in reality not an arch at all, but simply an arrangement or *scheme*.

THE GOTHIC ARCH.

Bisect the line *a b*, Fig. 56, with *c d*, and draw *a d*; from these two points with the compass

opened to more than half their distance draw the arcs $s f$. Through their intersections draw a line meeting $a b$ in g , from which point with the

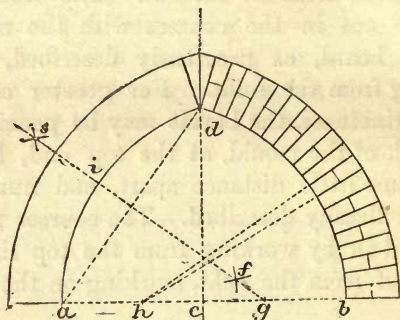


Fig. 56.

compass opened to a , draw the curve $a i d$, and by extending the compass, its parallel curve. From h draw the curves on the right-hand side. The bed joints radiate from h and g , as shown by

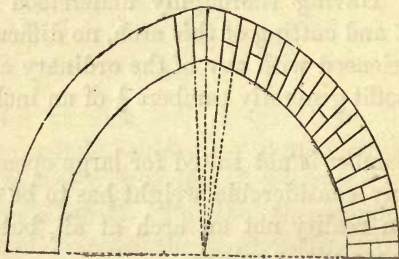


Fig. 57.

dotted lines. To do away with the very wedge-shaped key, the joints are sometimes radiated from the centre, as in Fig. 57. This key is also

objected to by some on account of the oddness of its appearance at the key—a “stretcher” on one side and two “headers” on the other (this is what bricklayers call keying in with a joint), to prevent which a “birdsmouthed” key is used, Fig. 58. In the last arrangement the arch has an odd number of bricks, in the two former an even number. Whatever objections may be urged

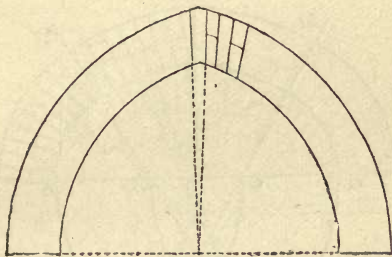


Fig. 58.

against the appearance of Figs. 56 and 57, the birdsmouthed key in Fig. 58 is decidedly wrong:—

“The essential character of the Gothic arch is derived from the absence of the key-stone, and from the presence of the perpendicular joint or opening in the centre where the archivolts rest against each other. Until we find this feature, Gothic architecture does not exist.”—*Normandy: Architecture of the Middle Ages.*

Fig. 56 is made up of two segments of a circle, and the mould is obtained in the same way as that for the segment. The moulds for Figs. 57 and 58 are obtained in the same way as that for the camber, the bricks being all of a

different bevel and length. These like the camber are *schemes*, not arches, as the bed joints do not fall within the *lines of radii*.

THE ELLIPSE GOTHIC ARCH.

Divide the span $a b$, Fig. 59, into three equal parts; take two parts in the compass, and with one leg fixed at a draw the arc $d e$, and from d

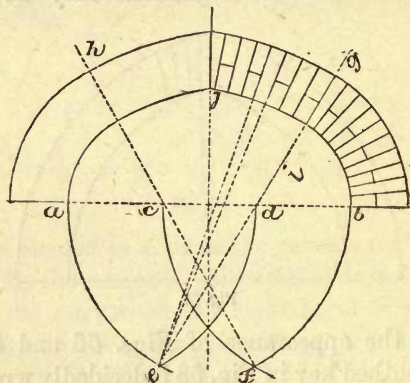


Fig. 59.

the arc $a e$. In the same way draw the arcs $b f$, $c f$. Through e and d draw the line $e g$; through $c f$ the line $f h$. With d as centre, radius $d b$, draw the arc $b i$, and from e , radius $e i$, the arc $i j$. The points from which the joints radiate are shown by dotted lines. Two different face moulds are required for this arch.

THE SEMI-ELLIPSE ARCH.

Divide the span $a b$, Fig. 60, into two equal parts, $a c$, $c b$, and $a c$, into six equal parts, 1, 2,

3, 4, &c. From c towards b measure off two of those parts, and with the distance $4d$ in the compass, and one leg fixed at 4, draw an arc cutting the centre line in e . Through $e d$ draw the line ef ; with d as centre, radius db , draw the arc bg , and from e with radius eg , the arc gh . Two ways are here shown of putting in the courses—one in which the joints radiate from their centres

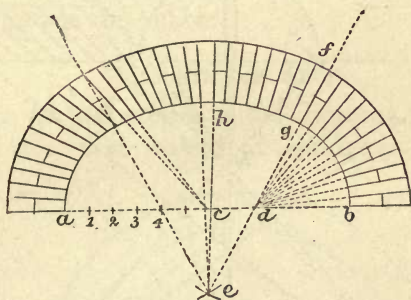


Fig. 60.

or foci $d e$, the other from c the centre of the opening. In the second method the lengths and bevels of each brick would be different. The first is an *arch*, the second a *scheme*, and is never adopted except in face work when, in the opinion of some people, it is desirable to have the courses all one thickness, even at the loss of strength. In the second method the mould, lengths, and bevels are taken off in the same way as those of the camber.

THE VENETIAN ARCH.

This so-called arch, Fig. 61, is made up of the camber and semi, and was a few years ago very much used in the construction of three-light

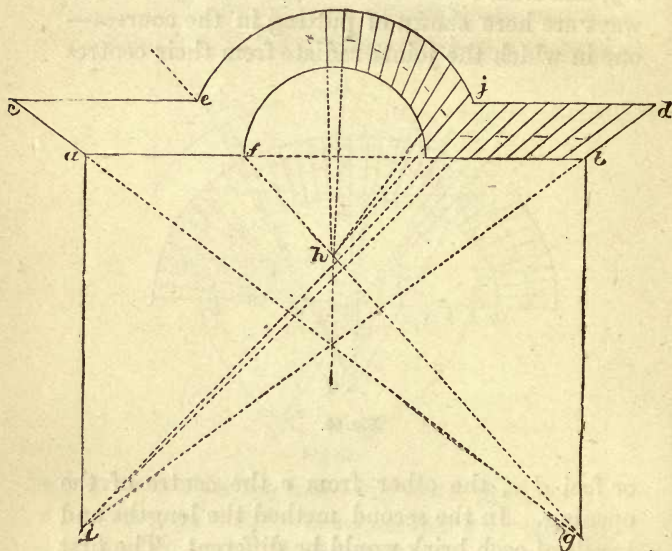


Fig. 61.

windows, sometimes with and sometimes *without* supporting mullions. Without mullions it is a very weak construction, and incapable of carrying much weight. But in this case it is generally allowed to have a bearing on the head of the solid window frame by showing less than $4\frac{1}{2}$ inches on the soffit. It is sometimes relieved by a gauged discharging arch above it. Having drawn the

semi, draw the parallel lines $a b, e d$, and through their points of intersection $e f$ the line $e g$. A line from g through a will be the line of skew-back. This repeated on the opposite side will find i . Next draw the angle brick j , the joints in the semi radiating from h , and the joints in the camber from i . Two different face moulds are required, which with the lengths and bevels of the courses must be taken off in the same way as described in the camber.

THE SCHEME ARCH.

Fig. 62 is the same as the segment, with this difference, that instead of springing from its

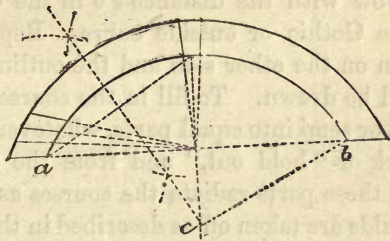


Fig. 62.

proper skewback $c b$, and its courses radiating from c , the curve is brought down to a level line or very near it, and the joints radiated from the centre of the opening in the level line. The *scheme* is the offspring of an antiquated and bad taste, and is not much used in the present day. One would think that its ugliness and want of truth would entirely forbid its use. It is treated by the cutter in the same way as the camber arch.

THE SEMI-GOTHIC ARCH.

To draw the semi-Gothic, Fig. 63, bisect (divide

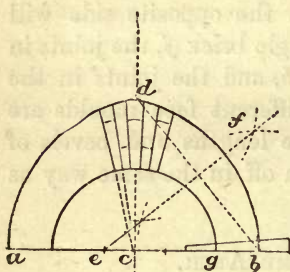


Fig. 63.

into two equal parts) the line ab with the perpendicular cd , and having determined the height of the apex d , from d draw the line db , and from these two points the arcs through which the line ef passes, intersecting the cord ab

in e . Now with the distance eb in the compass draw the Gothic or outside curve. Repeat this operation on the other side and the outline of the arch will be drawn. To fill in the courses divide the soffit or semi into equal parts, whatever a brick will work or "hold out," and from the centre c through these parts radiate the courses as shown. The moulds are taken off as described in the bullseye, and traversed from the key downward to the springing, taking care that the soffit mark on the mould always comes on the soffit of the arch. Having done this, mark on the mould the length of each course, which will also give the bevels of the top ends of the courses. The mould is shown on the springing course with the length and the outside bevel marked on it; g is the soffit mark to cut to; allowance must be made for the joint.

GOTHIC ON CIRCLE ARCH.

Fig. 64 shows the way to set out the moulds for a Gothic arch in a turret or bay that is circular in plan. Draw the elevation of the arch and the plan of the wall. A little considera-

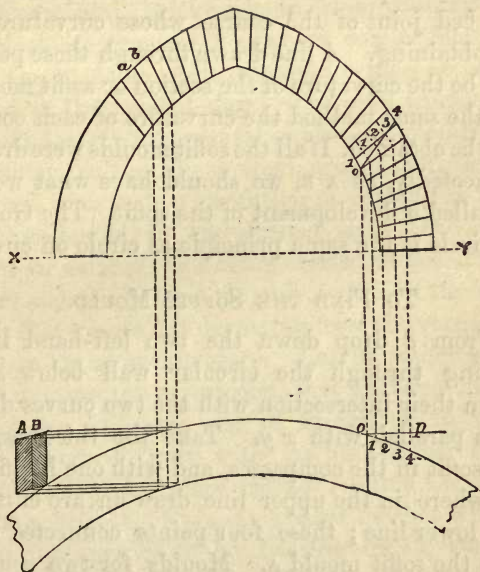


Fig. 64.

tion will show that the face of each course has a different curvature or "sweep," that at the springing having the greatest—equal to the wall itself—and the key the least, the curvature becoming less as the courses approach towards an upright position. A separate section mould must therefore be obtained for each course. Divide the bed



joint of the course o' whose curvature is required into a number of equal parts, from which drop lines square with $x y$, and intersecting the outside curve in $o, 1, 2, 3, 4$ in plan. Draw $o p$ parallel with $x y$, and transfer the distances 1, 2, 3, 4 from $o p$ in plan to lines or ordinates square with the bed joint of the course whose curvature we are obtaining. A line drawn through these points will be the curvature of the section or soffit mould. By the same method the curvature of each course may be obtained. If all the soffit moulds were drawn connectedly, as $A B$, we should have what would be called a development of the soffit. The Gothic on circle is the same principle as circle on circle.

TO FIND THE SOFFIT MOULD.

From a drop down the two left-hand lines passing through the circular wall below $x y$. From their intersection with the two curves draw lines parallel with $x y$. Take the thickness of the soffit in the compasses, and with one leg fixed anywhere in the upper line draw an arc cutting the lower line; these four points connected will give the soffit mould A . Moulds for two course, a and b , are shown; the others are obtained in the same way. This arch in practice is generally cut by rule of thumb, or what workmen call "near enough," and rubbed down to a suitable shape when the building is up, and its faults hidden with stopping of the colour of the bricks. But where perfect accuracy is required the moulds must be obtained as shown.

SECTION IV.

ORNAMENTAL BRICKWORK.

Ornamental brickwork in this country has reached its greatest height in connection with the Queen Anne style of architecture, as elaborated in the present day. The oriel windows of the Tudor, the ornamental gables and picturesque chimneys of the Elizabethan, are all merged into it, and with such a profusion of carving as to be unprecedented in any former age. Indeed, to such an extent is this being carried as to call forth from one of our most popular architects the assertion that we are fast departing from the vernacular of our street architecture. Let us rather say, if we may use the expression, that we have entered into the Augustan age of brickwork, in which the stuccoed front with its hidden carcass of "shuffs" and "place bricks"—often the refuse of the brick-field—is superseded by that which is what it appears to be, bearing on its face the unmistakable stamp of truth!

THE NICHE.

Figs. 65, 66, and 67 are the elevation plan and section of a niche in Flemish bond. This is considered by bricklayers to be one of the most artistic pieces of work in connection with their trade. There are two kinds of niches, the semi and the

elliptic. In the former it is circular in plan and elevation, in the latter it is elliptic in plan and circular in elevation. If that in our illustration be understood, no difficulty will be experienced with

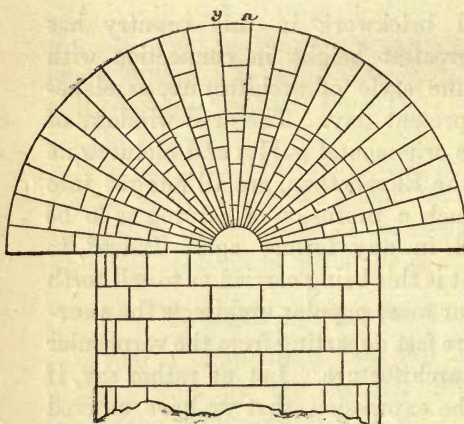


Fig. 65.

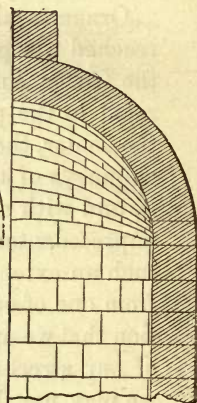


Fig. 67.

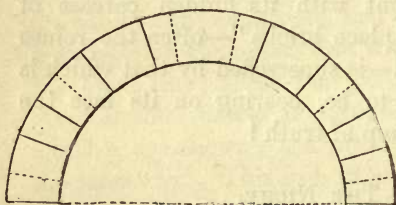


Fig. 66.

the others. The back or upright part is built to a template forming a semicircle, and the bond set out as shown on plan Fig. 66, the joints of one course being shown by thick lines, and those of the

course below by dotted lines. But it is the hood, the more difficult part, that we wish to explain. To make the centre, two pieces of wood, each a semi of the same circle as the niche, are nailed together with brackets in the internal angle (Fig. 68), and the space between the brackets filled in with core, pieces of bricks and mortar, and the surface finished with plaster of Paris, by means of a template a little more than a quarter of a circle (called the generating circle) fixed with a gimlet to the back of the bottom semi. The

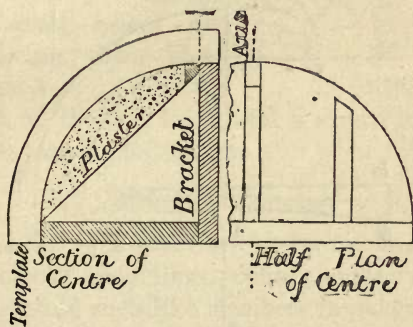


Fig. 68.

template rotating upon the gimlet as an axis, with the other end of it carried round the edge of the upright semi, a quarter of a sphere will be described or generated.

We have now got the centre or turning piece. Next draw the front arch as an ordinary semi arch, and mark the same number of courses on the top of the centre to represent the soffits. Then with

a plianth straight-edge or the rotating template, mark the courses on the plaster centre, all meeting in a needle-point where the gimlet entered; but as the bricks cannot be so finely cut, a small semicircle or "boss" is introduced of such a size that the bricks at the points where they meet it will be in thickness about half an inch. The courses are all of the same length and bevel, and the soffits must be bevelled in the same way as those

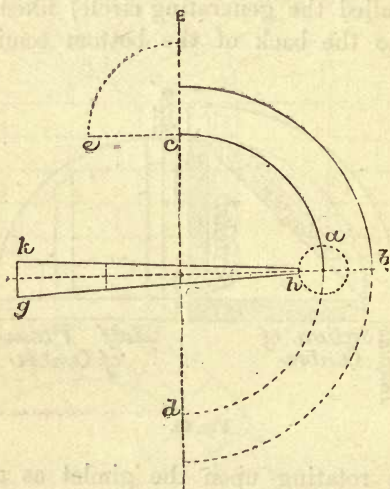


Fig. 69.

of an ordinary semi arch; and by looking at the elevation and section we see that the hood is made up of a series of semies increasing in size from the "boss" to the face arch.

THE NICHE MOULD.

The length of the course must be measured from where it meets the "boss" to the outside of the 9-inch face arch. From *h*, Fig. 69, draw a line square with *c d*, and on it mark a distance *f h* equal to the arc *a c*, and from *f* a distance *f g* equal to *c e*, making *g k* equal to *g' k'* in elevation (Fig. 65); connecting these two points with the circle *h* we obtain the mould. The length of *c a* is obtained by dividing it into small spaces and transferring them along the line *h f*; *f g* is the length of the key brick, and is shown turned up into its proper position *c e*.

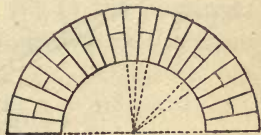


Fig. 70.

MOULDED COURSES.

It is the work of the bricklayer to cut and form all kinds of mouldings, dentils, entasis columns, flutings, and such like members in gauged work, leaving the more intricate, such as design and foliage, to be executed by the carver. Fig. 71 shows the kind of box that is used for cutting moulded bricks to any required section—in this case an ogee. The box is generally made to hold two headers or one stretcher. The brick or bricks, having been squared and rubbed down to the required thickness, are placed in this box and with the bow-saw roughly cut out, and then rubbed down to the section of the box with a

rasp, and sometimes a piece of straight gas-pipe to form the hollow members, the bricks being

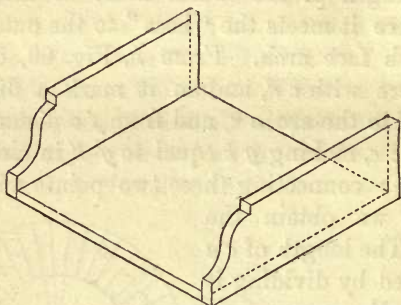


Fig. 71.

very soft. Care must be taken that the bricks be not wedged up or cramped too tightly in the box so as to "flush" the edges; and here we might mention that it is sometimes advisable to work the bricks a little wide, that in case of "flushing" they may be brought up to an arris by a rub or two on the stone. The cross piece or pieces on the top of the box are omitted for the sake of clearness.

ORNAMENTAL ARCHES

are those that have moulded soffits; and in such as the semi and segment, and in fact all that have the courses to one bevel, the moulding may be worked square, and applying the face mould cut in every respect similar to an arch with a square soffit. In this case one bed (the bottom one) will be square with the soffit,

and the other very much wedge-shaped. The courses must be cut rights and lefts, but the key and two springing bricks must be wedge-shaped from both beds, otherwise they will want bedding up with large joints to fit the centre, and thus spoil the appearance of the arch.

When a camber, or any arch whose courses have different bevels, has to be moulded on the soffit, the bricks must *first* be bevelled and afterwards moulded, and, lastly cut to the required shape and length by the application of the face mould, as before described.

THE ORIEL WINDOW

belongs peculiarly to ornamental brickwork (stone constructions being entirely excluded from this work), and we may add red brickwork. The first thing to be considered in connection with the oriel is its counterbalance. In all heavy projections in brickwork York flagging stones are employed; they are built into the main wall from which the projection starts, projecting to a distance suitable for the work. The weight of the projection on the stones is counterbalanced by the greater weight of brickwork on the other ends of the York slabs. But in the present case a girder or rolled iron joist, running in the direction of the wall line, and entering some 12 inches into the brick wall forming the side jambs, would have to be placed sufficiently low to allow the floor boards to pass over it. The flags and the weight upon them would be counter-

balanced by the girder. The principle of counterbalance is known to bricklayers by the name of "tailing down."

The whole of the oriel (Fig. 72) as shown

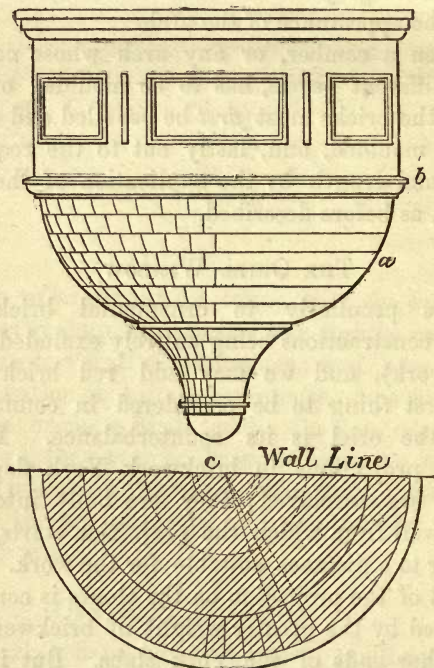


Fig. 72.

would be in brickwork, "gauged" and set in putty. The projecting courses, as the moulded string *b*, and the window-sill would be covered with 5-lb. lead, slightly projecting to form a drip for the water or rain.

The base here shown would be surmounted with mullions in brick or wood (most likely wood on account of its comparative lightness), and finished either with a semi-coned tiled roof or a balustrade. Windows of this type may be seen at Carlyle House, Chelsea Embankment; and the Agnew Picture Gallery, New Bond Street.

The bricklayer when setting out the work must strike all the successive courses from one point, *c*, regulating the length of the radius-rod for each course. Each course must radiate from *c*, as shown in plan, and the face of each brick be worked to the required sweep or curve. The bevels (which will be different for each and every course) will be obtained by placing the stock of the bevel on the line representing the bed, and bringing the blade to coincide with that portion of the curve representing the course we are about to cut. Let the bevel of the course marked *a* be required. Place the stock of the bevel on the third line below the moulded string *b*, and shift the blade until it fit the curve of the course *a*. The bevels for each course must be obtained in the same way. The plan in this figure may be considered as a horizontal section just above the string course *b*.

ORNAMENTAL GABLE OR PEDIMENT.

Figs. 73 and 74 are part front and end elevations of an ornamental gable or pediment. The moulding is composed of the members known as

the ovolo, the cavetto, and the ogee. In ornamental brick copings it is usual to form the top fillet with two courses of red tiles, well soaked and closely and neatly set in cement, with the

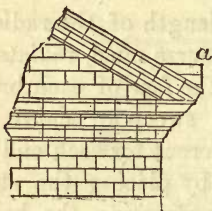


Fig. 73.

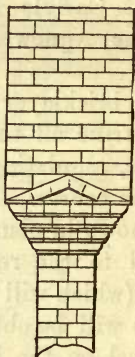


Fig. 74.

joints properly broken, as here shown. Sometimes lead is substituted for tiles. Here we have shown a gablet, *a*, but in practice the tiles are more frequently brought down to the bottom of the coping, the gablet being dispensed with.

GOTHIC WINDOW.

Fig. 75 is a two-light ornamental Gothic window with 2-inch beaded or chamfered reveals. The whole of the work under the large arch would be recessed back from the general wall line. The side piers *A* and *B* for uniformity sake might be built in half bond, similar to that

of the 9-inch mullion; but the proper bond would be to start from the reveal with a header and closer, the same as that shown on the reveal under the large arch. The tympanum is filled in

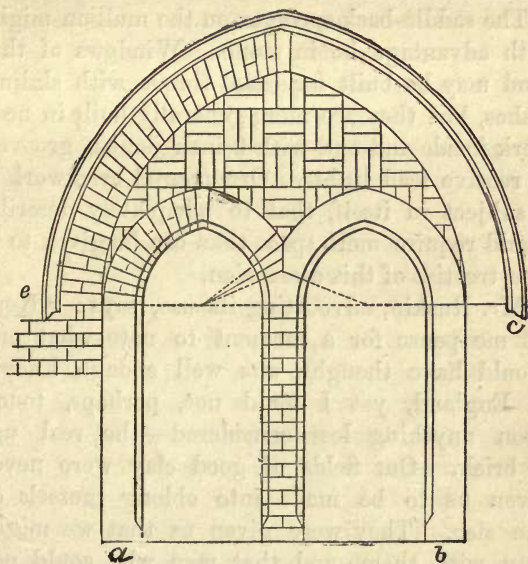


Fig. 75.

with $4\frac{1}{2}$ -inch work in 9-inch blocks, each block being made up of three bricks, and called "blocking courses."

The label or dripstone, *c e*, enclosing the large arch, for the sake of contrast might be in Portland stone. The whole of the work here shown, excepting the reveals of the large opening, might be in "gauged" work or in "axed" work; or the

arches alone might be "gauged" or axed, with the tympanum filled in with good building bricks, selected for colour and shape and neatly pointed, making a very effective as well as economical ornamental feature.

The saddle-back springer on the mullion might with advantage be in stone. Windows of this kind may be built for cased frames with sliding sashes, but they are more generally built in neat work inside and out, with 9-inch jambs, grooved to receive lead lights. Ornamental brickwork is a subject in itself, that to adequately describe would require more space than can be given to it in a treatise of this dimension.

Mr. Ruskin, advocating its use, says: "Here let me pause for a moment to note what one should have thought was well enough known in England, yet I could not, perhaps, touch upon anything less considered—the real use of brick. Our fields of good clay were never given us to be made into oblong morsels of one size. They were given us that we might play with them, and that men who could not handle a chisel might knead out some expression of human thought. In the ancient architecture of the clay districts of Italy, every possible adaptation of the material is found, exemplified from the coarsest and most brittle kinds, used in the mass of the structure, to bricks for arches and plinths, cast in the most perfect curves, and of almost every size, strength and hardness; and moulded bricks wrought into flower work and

tracery as fine as raised patterns upon china. And just as many of the finest works of the Italian sculptors were executed in porcelain, many of the best thoughts of their architects were expressed in bricks, or in the softer material of terra-cotta ; and if this were so in Italy where there is not one city from whose towers we may not descry the blue outline of the Alps or Appennines—everlasting quarries of granite and marble—how much more ought it to be so among the fields of England.”—*Stones of Venice*, vol. ii., p. 260.

Judging by the remarks in the above quotation, one is led to think that the brickmakers of mediæval Italy were more skilled in their craft, or at least happier in results, than their fraternity of modern times ; for, with few exceptions, we have found moulded work wanting in that truthfulness of form which distinguishes cut or gauged work. Doubtless this, in great measure, is due to the large amount of unskilled and juvenile labour employed in our brickworks, to the careless manipulation of the work, and the hurried demand for the material. To be assured that true form *can* be obtained in ceramic wares, one has only to look at the Natural History Museum, London.

SECTION V.

ROOF-TILING, POINTING, Etc.

TILING.

TILING is a branch of the bricklayer's trade, and owing to the rage for red-brick buildings is now very much in use. One advantage of the tiled roof is that it is cool in summer and warm in winter, but on account of their weight stronger timbers are required than for slates. The Broseley tiles are considered the best; they are $10\frac{1}{2}$ inches long, 6 inches wide, and $\frac{3}{8}$ of an inch thick, and have three nibs or projections at the head for hanging. Good tiles are fairly smooth and slightly vitrified. Those of a bright red or clayey colour, with no vitrification, are absorbent, and not so capable of resisting the weather. Six kinds are used in good work, viz. under-eaves or three-quarter tiles, plain tiles, hips and valleys, ridge tiles and tile-and-a-half, the last being used for cutting up to valleys and hips, and forming gables, so as to do away with the half tile that would be required to break joint. Valley and hip tiles are purposely made to suit the angles of the roof. As the tiles come to the hand of the tiler he should throw out the straight ones to be used by themselves, while those that have a hollow bed should be also kept by themselves, as the straights will not lie close on the hollows. Good tiling is characterised by the tails of each course fitting closely upon the backs of the tiles in the course below them; by the cross

joints or "perpend" running in straight and regular lines from eaves to ridge, the vertical joint between each two tiles coming immediately in the middle of the tile below them; by the hips and valleys being in the same plane as the sides of the roof of which they form a part. It is a common sight to see hips standing up above the roof, so as to have more the appearance of ridges than hips. As the tiles are ordered before the roof is on, the angles should be set out and sent to the tile-maker to insure getting them to the required angle. The contained angle of hip tiles is made 10° greater than the contained angle formed by the intersection at the hip of the two sides or planes of the roof, to allow for the tilt and the thickness of the two eaves-tiles. For the same reason the valley-tile is made 10° more than the re-entering angle of the roof. In our experience we have frequently found that the contained angle has been guessed at or obtained by some "rule of thumb," and with the consequence that generally ensues from such work, viz. that the angle contained within the hip tile has been either too acute or too obtuse.

Tiles are either laid dry on close boards, with battens above for hanging them, or on open battens, in which case they should be bedded in lime and hair mortar. The most modern and improved way of hanging is shown in Fig. 76. The boards are 6 inches wide and are feather-edged, the top edge being $\frac{3}{4}$ of an inch thick. Here we have a boarded roof without battens, and one that will

keep out the weather if the tiles should get broken, for the rain would cause the wood to expand, and thus tighten the joints of the boards, to the exclusion of all rain. The first course—the eaves and under-eaves—should be bedded in hair mortar. The “lap” (the distance that the tail of the third tile overlaps the head of the first) should be

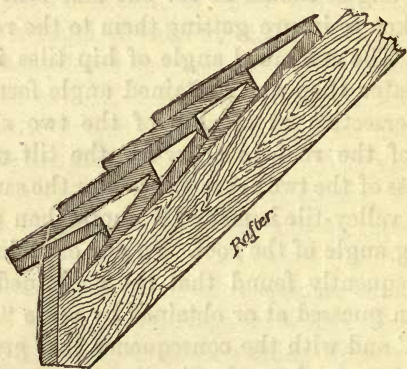


Fig. 76.

3 inches. The “gauge” (the distance between the tails of two consecutive courses) can always be obtained by dividing the length of the tile (measured from the under side of the hanging nibs) less the lap by two. Thus, $(10\frac{1}{2} - 3) \div 2 = 3\frac{3}{4}$, the “gauge.”

ROOFS HAVING DIFFERENT PITCHES.

When roofs of different pitches intersecting in hips and valleys occur, the tiler has generally a

deal of trouble, and consequent waste of time, through carpenters frequently insisting upon intersecting the battens; and very often after much time has been wasted, and a portion of the tiling done, it is found necessary to tear off all the battens to correct the error.

The following rule will prevent such an error. Draw the plan of the two roofs (Fig 77), of

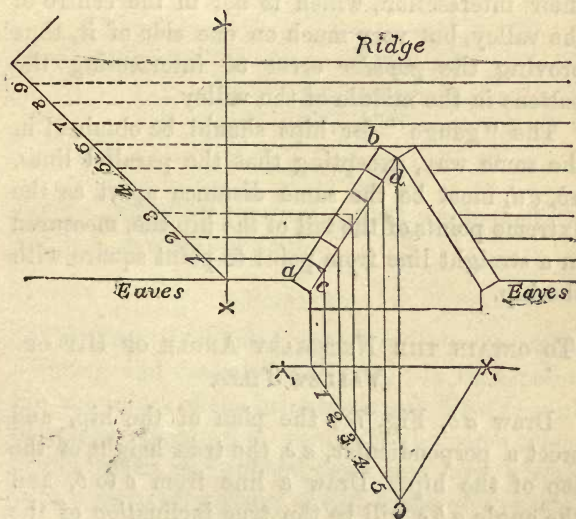


Fig. 77.

different pitch, and from the centre of the valley set out two parallel lines, *a b*, *c d*, representing the true width of the tails of the valley tiles, which is from $1\frac{1}{2}$ to 2 inches. On *xy* at right angles with the eaves of the main roof draw its section, on which set out the gauge 1, 2, 3, &c.,

and drop lines square with xy and intersecting the line ab . From these points of intersection square the short lines across the valley, and from where they intersect the parallel cd draw lines square with $x'y'$ and intersecting a section of the smaller roof. The distance between any two points on $x'g$ will be the "gauge" for the smaller roof. The line 3 on each section is drawn to their intersection, which is *not* in the centre of the valley, but very much on one side of it, thus proving the *popular* error of intersecting the battens in the middle of the valley.

The "gauge" for hips should be obtained in the same way, excepting that the parallel lines, ab, cd , must be the same distance apart as the extreme points of the tail of the hip tile, measured in a straight line from point to point square with the hip.

TO OBTAIN THE NECESSARY ANGLE OF HIP OF VALLEY TILES.

Draw ab , Fig. 78, the plan of the hip, and erect a perpendicular, ac , the true height of the top of the hip. Draw a line from c to b , and the angle abc will be the true inclination of the hip. Draw ed square with ab , cutting the eaves, and from f a line square with cb ; with this as radius, from the point f draw the semicircle, and from where it cuts ab draw the lines eg, dg ; egd is the angle required for the hip tiles, or in other words it is a section or cut through the roof at right angles with the hip. The angle for

valley tiles is obtained in the same way, remem-

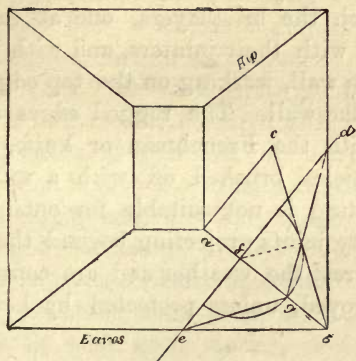


Fig. 78.

bering that the hip is a salient angle and the valley a re-entering angle.

POINTING.

Pointing is divided into two classes, tuck-pointing and flat-joint pointing. In tuck-pointing the joints of the brickwork are filled in with mortar or stopping, of generally the same colour as the bricks, and rubbed down to a level surface with a piece of sacking or soft brick of the same colour as the work, and a putty joint made of lime and silver-sand placed upon it. Stone lime should be used for outside work.

The mode of working is to have a parallel rule from 8 to 10 feet long, 5 inches wide, and $\frac{1}{2}$ an inch thick, with one feather edge and four cleats $\frac{1}{8}$ of an inch thick tacked on to the back to

afford room for the putty that is cut off to fall through. The putty is spread out on the rule from which the bricklayers, one at each end, take it off with their jointers, and with the rule against the wall, working on the top edge, transfer it to the wall. The ragged edges are then cut off with the Frenchman or knife, and the loose particles brushed off with a soft brush. Tuck-pointing is not suitable for outside work, as the putty joints projecting beyond the general surface arrest the weather and are consequently soon destroyed, unless protected by heavy projections.

FLAT-JOINT POINTING.

This is the most general and durable kind of pointing. It should be made up of washed sand and stone lime several days at least before using it, that it may by the process of retempering acquire toughness, which will add very much to its durability and facility of working. The joints should be finished flush with the work (excepting in "weather-jointing," when the top of the joint should be kept back $\frac{3}{8}$ of an inch, and the bottom flush to shed the rain) and neatly cut off top and bottom with the Frenchman, and brushed off. To ensure good pointing, the work should be well raked out and wetted not sparingly. If the joints are deep they should be filled in by going over them twice with tolerably stiff mortar to prevent cracking, and the work done with *pointing trowels*. Jointers should not be used under

any pretext. In first-class work the pointing is done as the work proceeds during erection, and forming one body with the building will, if the mortar be good, last for many years.

Malm work for tuck-pointing is generally stopped in with mortar, coloured with yellow ochre (2lbs. of ochre to each hod of mortar), but it will be found best to use *no* colour in the stopping, as by its earthy nature it very much injures the setting and hardening properties of the lime, which in a great measure accounts for so much pointing perishing soon after it is done. Stop the work in with good mortar, as described in flat-joint pointing, and rub it down with a soft malm, leaving the dust on the work, and with a soft stock brush go over it lightly with hot alum water. One pound of alum to 3 gallons of water.

White Suffolk bricks for tuck-pointing, are treated in the same way, rubbing the work with a soft white Suffolk instead of with a malm.

Red work for tuck-pointing is stopped in with mortar coloured with Venetian red and Spanish brown, with sometimes a little vegetable black added. The colour of the stopping must be determined by the colour of the bricks, so as to match them. It is best to avoid colouring the bricks, but when stopped in rub them down with a soft brick, and apply alum water or white copperas, as already described. One pound of copperas to 3 gallons of water. The appearance of red brickwork is often spoilt through the application of colour.

To clean down red work, mix a pint of spirits of salts with a pailful of water. This applied with a stock brush will leave the work clear of all lime spots, &c. It may be done on work recently erected, in which the joints have been struck during erection, and without injuring them.

Copperas is very much used in connection with stock work, especially when the bricks are inferior or of a bad colour. One pound of green copperas is melted down with every 5 gallons of water. It should be mixed several days before required, and enough made to finish the job, that it may be all one colour. A small nob of lime mixed with the copperas very much heightens its colour. The copperas should be tried on the work to match it before being generally used, and weakened down by the addition of water if found necessary.

BURNING CLAY INTO BALLAST.

The use of burnt ballast is increasing every day, both for purposes of mortar and concrete. The chief reason for this is its cheapness in comparison with the cost of sand, for while sand costs from 5s. to 7s. a cube yard, varying according to the locality, burnt ballast can be produced, including all materials and digging of clay, with a run of about 60 yards, at 2s. 6d. a cube yard. While we *reiterate* that for mortar nothing better than clean sand of a sharp angular grit can be used, we do not wish to be understood as condemning the use of burnt ballast. Thoroughly burnt and cool, with

the large aggregations (sponge-like lumps whose parts touch each other here and there, and are held in contact by vitreous matter) broken up, and the whole mixed with a fair proportion of Thames ballast or clean gravel (see previous remarks on this subject in Article on Concrete), is capable of making a good concrete, for the absorbent nature of the ballast attracting the silicates of the cement or lime, which entering the pores form so many threads or ties binding the whole mass together, and unlike Thames ballast, with its non-absorbent and smoothly water-worn surfaces, which simply beds itself in the matrix with comparatively little adhesion.

Stiff or strong clay, just as it is dug up, is the best for burning, as it requires the least firing and will make the best ballast. The heap is commenced by forming a cone of clay, about 3 feet in diameter and 5 feet in height, formed round a piece of pole placed on end as a centre. Fires are then made round the cone by placing bricks on edge forming a channel leading up to the centre. These are filled with wood and coal, and covered over and cased with a layer of clay about 6 inches thick before lighting. As the fire burns through it must be drawn down, which is done by means of long-handled prongs made specially for the work, and strewn with small coal called "slack," and covered with another layer of clay. The thickness of the layers of clay may be increased as the work proceeds, until they become from 18 to 24 inches, not forgetting the sprinkling of

“slack” on each layer of clay. Care must be taken that the fire be drawn down, as it naturally draws to the top, and the unburnt portions thrown up into the fire. When the clay is thoroughly burnt the fire will go out.

BUILDING ADDITIONS TO OLD WORK.

When building additions to old buildings, it frequently occurs that the old work is found to be considerably out of perpendicular, generally overhanging. In such a case it is best to carry up with the new work, just where it joins with the old, a pier or pilaster, forming a break in the wall line, which will enable the bricklayer to keep the new work upright and hide the fault of the old, which otherwise would be exposed by junction with the new. The projection of the pilaster will of course be regulated by the amount that the work is out of the upright.

FIRE-PROOF FLOORS.

Fire-proof floors are now very rarely constructed in bricks, being almost entirely superseded by tile arches brought to a level with concrete, or constructed with rolled joists and concrete alone, or with cement and breeze, but more generally with Dennett's Patent, which is a concrete composed of broken bricks and gypsum. But in very large warehouses, and where great weights have to be carried, the fire-proof floors are still constructed with brick rings carried on rolled girders.

SECTION VI.

APPLIED GEOMETRY.

Geometry of all studies is to the artisan the most attractive and useful. The problems given here are such as may be applied by the bricklayer to every-day practice, and therefore come within the meaning of the term *applied geometry*. But we would advise the young artisan not to rest satisfied with a knowledge of the few problems given herein, but to take up the subject as a separate study, and familiarise his mind with its principles, so as to be able to apply them generally and with understanding.

To draw a square whose superficial area shall equal the sum of two squares whose sides are given.

Let AB (Fig. 79) be the given sides. Draw the lines CD, EF at right angles, and from G set off GH equal to A , and GK equal to B : a line drawn from H to K will be the side of the required square. On GK complete the square GM, NK ; and on GH the square $HLEG$; and on HK the square $HKOP$. The area of this square will

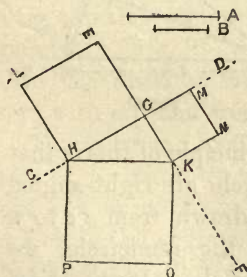


Fig. 79.

equal the combined areas of the two smaller

squares. To make this more clear, suppose the line A to be 8 inches and B 6 inches. The square of A would be 8×8 equal to 64; and the square of 6 would be 6×6 equal to 36, which added to 64 makes 100. By drawing A and B square with each other and joining their extremes with a straight line, we will find that line to measure exactly 10 inches, and the square of that will be 100.

The principle of this problem is that a square erected on the hypotenuse (the longest side) of a right-angled triangle is equal to the sum of two squares, erected on the base and perpendicular of the same triangle. Its application to practice is shown in the article on "Setting out Building."

To draw a right-angled triangle, base $1\frac{1}{2}$ inches, height $\frac{1}{2}$ inch.

Draw a semicircle of $1\frac{1}{2}$ inch diameter (Fig. 80), and from *d* erect the perpendicular *d e*: a line drawn from *e*, $\frac{1}{2}$ inch above the base line *a c*, will cut the semicircle in *b*; lines drawn from *a* and *c* to *b* will form

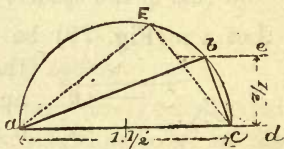


Fig. 80.

the required triangle. The principle of this is that all triangles within a semicircle are right-angled triangles. If the lines be drawn from *a c* to *E* or to any other point in the semicircle, we shall get a right-angled triangle. Its practical application is seen in the article on "Setting out Building."

To draw an arc by cross-sectional lines.

On ab , the span (Fig 81), erect the perpendiculars, de , equal to twice the required rise.

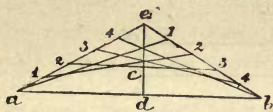


Fig. 81.

Divide ae into any number of equal parts, 1, 2, 3, 4, and eb into the same number of parts, and draw cross-sectional lines as shown. A curve traced through the intersections will be the required arc.

Another method practised (we do not recommend its use) sometimes by carpenters for getting out turning-pieces for the bricklayer. Span 6 feet, rise $1\frac{1}{2}$ inch. Divide the span into a number of equal parts, say six, and from the points erect perpendiculars, measuring upward $\frac{1}{2}$ inch on the first, an inch on the second, and $1\frac{1}{2}$ inch on the third, which in this case is the centre line. Treat the other half of the span in the same way, and with a flexible straight-edge fixed at the springing points ab (Fig. 81) force it upward until it stand over the distance marks on the perpendiculars, and with a pencil trace the arc or curve.

The foregoing methods do away with the necessity of laying down a large platform and getting out a long radius-rod; the camber, for instance, which is the segment of a circle described by a radius-rod of 70 feet $2\frac{3}{8}$ inches in length.

To describe a flat arc (camber for instance) by mechanical means.

Let ab (Fig. 82) be the cord of the arc. Bisect

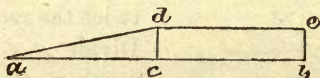


Fig. 82.

ab at c by the perpendicular cd , and make cd equal to the height of the segment. Draw de parallel to ab , and make de a little larger than ad . This template should be got out of a piece of timber, and by moving the whole of the template, so that the two edges da and de may slide on two pins, a and d , the angular point d of the template will describe the segment required, and if the pin be taken out of a and put in the point b , the other portion db of the segment adb will be described in the same manner. This method should be practised in preference to the methods previously described.

To find the joints of a flat arch without using the centre of the circle of which the arc is a part.

Having determined the number of voussoirs or

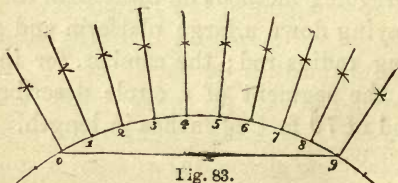


Fig. 83.

“courses,” 1, 2, 3, 4, &c. (Fig. 83), from these points

erect perpendiculars by intersecting arcs; these perpendiculars represent the joints. We need hardly to say that the practical application of this problem is to enable the workman to draw the courses or voussoirs in an arch similar to that given in the previous problem.

To draw the joints of a semi ellipse arch with mathematical accuracy.

The point *D* (Fig. 84) is the middle of the arch,

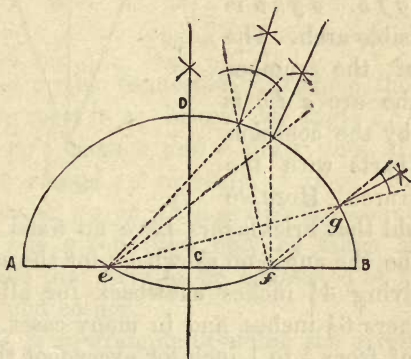


Fig. 84.

and the point *c* the middle of the springing line. With the distance *c A* or *c B*, from the point *D* describe an arc cutting *AB* at *e*, and also at *f*; *ef* are the foci. Let a joint be required at *g*. From *e* and *f* draw lines passing through *g*, and bisect the angle they make with each other, and from the point *g* erect a perpendicular, which will represent the required joint. The other joints are obtained in a similar manner.

Any two straight lines given to determine a curve by which they shall be connected.

Let $a b, c d$ (Fig. 86), be the given lines, and $c b$

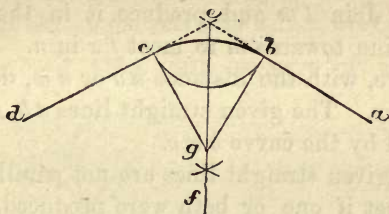


Fig. 86.

the points to be connected. Produce the lines until they meet in e ; bisect the angle ceb with the line ef ; from c and b draw lines at right angles to ab and cd meeting ef in g . From g , with distance gc or gb describe the connecting curve. The given lines may be taken as two brick walls that have to be connected or formed with a round corner.

Fig. 87 is an example in which the given lines

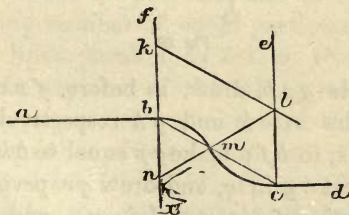


Fig. 87.

are parallel. From point b draw fx at right angles with ab ; and from c , ce , at right angles

with $c d$. On f mark a point k any distance from b less than $b c$. Draw $k l$ through k parallel to $b c$ and cutting $c e$ in l . From l as centre with the distance $l c$, which is equal to $b k$, describe the arc $c m$. Join $l m$ and produce it in the same straight line towards m to meet $f x$ in n . From n as centre, with the distance $n b$ or $n m$, describe the arc $b m$. The given straight lines $a b$, $c d$ are connected by the curve $b m c$.

If the given straight lines are not parallel, but would meet if one or both were produced, as $g h$ (Fig. 88), produced meets $a b$ in a , forming the

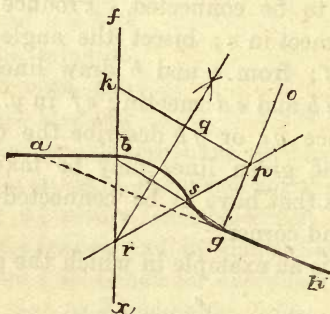


Fig. 88.

small angle $g a b$, draw, as before, $f x$ and $g o$ at right angles to $a b$ and $g h$ respectively. Take any point, k , in $b f$; make $g p$ equal to $b k$, and join $k p$. Bisect $k p$ in q , and draw $q r$ perpendicular to $k p$, meeting $f x$ in r . Join $r p$, and from p as centre, at the distance $g p$, describe the arc $g s$, meeting $r p$ in s . Then from the centre r , at the distance $r b$ or $r s$, describe the arc completing the

curve $b s g$, by which the given straight lines $a b$, $g h$ are connected.

To find the form or curvature of a raking moulding that shall unite correctly with a level one.

Let $a b c d$ (Fig. 89) be part of the level

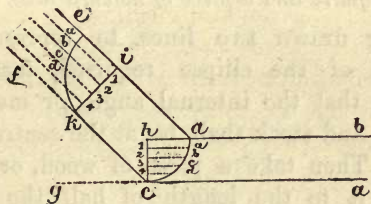


Fig. 89.

moulding (which we will here suppose to be an ovolo or quarter round), a and c the points where the raking moulding takes its rise on the angle, $f c g$ the angle the raking moulding makes with the level one. Draw $c f$ at the given angle, and from a draw $a e$ parallel to it; continue $b a$ to h , and from c make $c h$ perpendicular to $h a$. Divide $c h$ into any number of equal parts, as 1, 2, 3, 4, and draw lines parallel to $h a$, as 1^a , 2^b , 3^c , 4^d ; and then in any part of the raking moulding, as i , draw $i k$, perpendicular to $e a$, and divide it into the same number of equal parts as $h c$ is divided into; and draw 1^a , 2^b , 3^c , 4^d , parallel to $e a$. Then transfer the distances 1^a , 2^b , 3^c , 4^d , and a curve drawn through these points will be the form of the curve required for the raking moulding.

The method here shown is for an ovolo, but it would be just the same for any other formed moulding, as a cavetto, ogee, &c. This problem can be applied in the construction of pediments in "gauged" work.

To describe an ellipse by means of a carpenter's square and a piece of notched lath.

Having drawn two lines to represent the diameters of the ellipse required, fasten the square so that the internal angle, or meeting of the blade and stock shall be at the centre of the ellipse. Then take a piece of wood, or a lath, and cut it to the length of half the longest diameter, and from one end cut out a piece equal to half the shortest diameter, and there will then be a piece remaining at one end equal to the difference of the half of the two diameters. Place this projecting piece of the lath in such a manner that it may rest against the square on the edge which corresponds to the two diameters; and then turning it round horizontally, the two ends of the projection will slide along the two internal edges of the square, and if a pencil be fixed at the other end of the lath it will describe one quarter of an ellipse. The square must then be moved for the successive quarters of the ellipse, and the whole figure will thus be easily formed. This method is on the principle of the trammel. There are several other ways of drawing an ellipse, but for these the reader must be referred to a work on geometry.

*To draw a Gothic of any given height and span ;
or, in other words, an Ellipse Gothic.*

Let AB (Fig. 90) be the span and CD the height. Draw the line AB and bisect or centre it at c ;

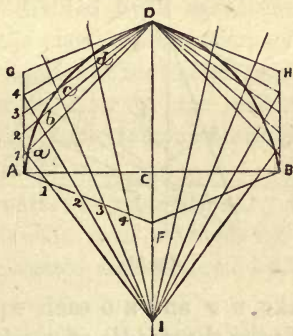


Fig. 90.

draw CD , and make CI equal to CD . Divide CD into three equal parts, and draw AG , BH parallel with CD , and equal to two-thirds ($\frac{2}{3}$) of CD . Make CF equal to one-third of CD , and draw AF , FB . Divide AF into any number of equal parts, 1, 2, 3, 4, and from i draw $i1$, $i2$, $i3$, $i4$. Divide AG into the same number of parts as AF , and draw $1D$, $2D$, $3D$, $4D$, and the intersection of lines will give the points in the curve, which must be drawn by hand. The other half must be found in the same way.

mathematical formula our calculation would stand thus :

$$\left(\frac{a^2}{c} + c d \right) \div 2 = \text{the length of radius re-}$$

quired. Or in plain words a^2 square, divided by c , plus $c d$ divided by 2 equal the length of radius. In the above explanation we have gone out of the beaten track for the purpose of making the rule clear to those of our readers who may not be familiar with trigonometrical and algebraic expressions.

It will, however, be recognised by some as the square of half the cord divided by the versed sine, plus the versed sine divided by 2 equal the radius.

For mensuration of brickwork the Author refers the reader to Mr. Hammond's "Practical Bricklaying," forming vol. 189 in this series.

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
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